DUPLICATE

METEOROLOGICAL OFFICE

Forecasting Research

Forecasting Research Division
Technical Report No. 113

TRIALS OF INCREASED VERTICAL RESOLUTION IN THE LIMITED AREA MODEL

by

C.A.Wilson and O. Hammon

MARCH 1995

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

ORGS UKMO F
National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

FORECASTING RESEARCH TECHNICAL REPORT NO 113

TRIALS OF INCREASED VERTICAL RESOLUTION IN THE LIMITED AREA MODEL

by

C. A. Wilson and O. Hammon

MARCH 1995

© Crown Copyright 1995

Forecasting Research Division
Meteorological Office
London Road
Bracknell
Berks
RG12 2SZ

This Technical Report has not been published. Permission to quote it must be obtained from the Head of Numerical modelling, Forecasting Research Divison.

TRIALS OF INCREASED VERTICAL RESOLUTION IN THE LIMITED AREA MODEL

CONTENTS

1. INTRODUCTION
2. OBJECTIVE VERIFICATION
3. SUBJECTIVE ASSESSMENT
4. CONCLUSIONS

1. INTRODUCTION

This technical report contains the results of the subjective and objective assessment of tests of extra vertical levels in the limited area model from the standard 19 levels (FIG 1.1). These were performed during May-June 1994 with two new sets of levels: there were 31 levels for both. The increased cost of ~50% run time was partly offset by the use of a longer timestep of 15 minutes for the physics, see **Technical Report 111** (Wilson, Hammon and Barnes 1994), which had a largely neutral impact on the quality of the forecasts.

Two convenient choices of levels were used:

a) the mesoscale set (**meslev**,FIG 1.2) which are concentrated in the lower atmosphere and particularly the boundary layer with 13 levels in the first 200hPa from the surface;

b) the levels as used at ECMWF (**eclev**), modified slightly to maintain the same top boundary as the current 19 levels; this set has 7 levels below 800hPa with a more uniform resolution in the free atmosphere and increased resolution of ~25 to 30hPa at jet levels compared to the current resolution there of ~50hPa. The ECMWF model has a bottom layer thicker by ~20m than the standard UM 19 layers. From 07/06/94-16/06/94 a slightly modified set of levels with the same bottom layer as operational were also run . The impact of this was negligible. For convenience these levels are referred to **eculev** (FIG 1.3 , TABLE 1.1).

Test forecasts to T+48 were run almost daily from 14/05/94 until 07/06/94 using both meslev and eclev; these were run from interpolated operational analyses and lateral boundary values. Full assimilation testing with increased levels requires new observation files and is best investigated with the parallel suite. The longer timestep of 15min was used for the physics which gave a 20% reduction in run time, which with a 50% increase in levels gave a net increase of 20% in run time, over the operational forecast.

The revised set eculev was run in parallel to the operational from 07/06/94 to 27/07/94. Verification results from all 3 periods of testing are given in section 2.

TABLE 1.1 UM 19 and 31 LEVELS (η)

19(UM)	31(eculev)		31(eclev)
.997	.997		.996
	.983		
.975			
	.959		
.930	.928		
	.891		
.870			
	.850		
.792	.807		
----------	----------	boundary	layer top
	.762		
.700	.717		
	.671		
	.626		
.600		19 (UM)	31 (UM)
	.581	.150	.155
	.537		.132
.505	.495	.099	.111
	.453		.090
.422	.413		.070
	.374	.056	.050
.355		.0296	.0296
	.337	.0147	
.300	.302		.0088
	.269	.0046	
.250			
	.237		
.200	.208		
	.181		

2. OBJECTIVE VERIFICATION

A limited amount of verification of some key parameters against operational analyses was performed daily. The parameters verified were pressure at mean sea level, 500hPa height, 250hPa temperature and wind, and 850hPa temperature.T+24 forecasts, over the whole LAM domain and area "5" (the UK to Iceland region) were verified. Only results for the whole LAM area will be presented here, since the results from the smaller area are largely consistent.

2. 1 COMPARISON OF MESLEV AND ECLEV -PERIOD 14/05/94 UNTIL 07/06/94

The largest benefit from extra levels was seen at upper tropospheric levels from the eclev set which had appreciable improved resolution in the free atmosphere and around jet level, giving a significant reduction in rms vector wind errors (**FIG 2.1**). The meslev set had similar forecast wind errors to the operational. Wind speed errors were also improved by using eclevs (**FIG 2.2**) with a smaller bias and rms speed error. Similarly the 250 hPa temperature bias and rms errors were reduced (**FIG 2.3**).

In the lower half of the atmosphere the impact of both sets of 31 levels was less beneficial. There was a worsening of the cold bias at 850hPa (**FIG 2.4**), particularly for the meslevs. This was caused by larger cloud amounts in the boundary layer and increased long wave cooling. For the meslevs this had a detrimental effect on the 500hPa height bias and also worsened the rms error compared to the operational model (**FIG 2.5**).

In terms of the surface pressure rms errors (**FIG 2.6**), the eclev set again showed the best performance. The meslev and operational forecasts verified very similarly. The additional resolution throughout the free atmosphere and around jet level appears to be more beneficial than extra resolution in the boundary layer for these basic forecast parameters.

TABLE 2.1 summarises the mean scores for all the parameters over the whole period.Also shown are the mean changes in bias and the percentage improvement/detriment (negative/positive values) in rms errors. Apart from the 2.6% worsening of 850hPa temperature errors the eclevs has generally smaller errors than the operational 19 level forecasts. The improvements of 10.8% and 7.2 % in upper level (250 hPa) temperature and wind errors are particularly noteworthy. The meslev errors are very slightly better at upper levels but are appreciably worse than operational for PMSL and at lower levels.

2. 2 COMPARISON OF ECLEV AND ECULEV -PERIOD 08/06/94 UNTIL 15/06/94

The bottom layer thickness ($\Delta\eta$=0.008) of the 31 levels based upon ECMWF layers was greater than the bottom layer used for the operational LAM ($\Delta\eta$=0.006). To see whether this was contributing significantly to the verification results the layer thickness was changed to be the same as operational. This would be more convenient since the processing and assimilation of ship winds assumes the bottom level to be ~25m. The changed set is referred to as eculev and for the period 08/06/94 until 15/06/94 both sets were used in parallel to the operational model.

Mean results 15/05/94-08/06/94, whole LAM area					
T850/K	mean	rms	sd	mean dif	%rms
oper	-0.27	1.25	1.22		
meslev	-0.41	1.40	1.33	-0.14	11.59
eclev	-0.32	1.28	1.24	-0.05	2.55
H500/m	mean	rms	sd	mean dif	%rms
oper	-3.70	13.86	13.24		
meslev	-4.59	14.26	13.39	-0.89	2.85
eclev	-4.02	13.57	12.84	-0.31	-2.07
PMSL/Pa	mean	rms	sd	mean dif	%rms
oper	-9.49	179.22	177.98		
meslev	-7.35	177.90	176.67	2.14	-0.73
eclev	-6.43	169.86	168.68	3.06	-5.22
T250/K	mean	rms	sd	mean dif	%rms
oper	-0.50	1.37	1.27		
meslev	-0.41	1.35	1.28	0.09	-1.41
eclev	-0.04	1.22	1.22	0.46	-10.75
250w/speed	mean	rms	sd	mean dif	%rms
oper	0.36	4.76	4.74		
meslev	0.43	4.75	4.73	0.07	-0.14
eclev	0.14	4.40	4.40	-0.22	-7.40
VWE250/m/s	mean	rms	sd	mean dif	%rms
oper	5.28	6.59	3.92		
meslev	5.27	6.58	3.94	-0.02	-0.06
eclev	4.92	6.11	3.61	-0.36	-7.21
		TABLE 2.1			

Mean results 08/06/94-17/06/94, whole LAM area					
T850/K	mean	rms	sd	mean dif	%rms
oper	-0.22	1.28	1.26		
eclev	-0.30	1.35	1.31	-0.08	4.80
eculev	-0.31	1.34	1.31	-0.08	4.55
H500/m	mean	rms	sd	mean dif	%rms
oper	-4.35	15.06	14.32		
eclev	-4.52	14.92	14.13	-0.18	-0.89
eculev	-4.72	15.02	14.17	-0.37	-0.24
PMSL/Pa	mean	rms	sd	mean dif	%rms
oper	-25.64	183.66	180.33		
eclev	-21.85	178.39	175.45	3.79	-2.87
eculev	-25.00	177.13	173.72	0.64	-3.56
T250/K	mean	rms	sd	mean dif	%rms
oper	-0.51	1.40	1.30		
eclev	-0.07	1.28	1.28	0.44	-8.22
eculev	-0.10	1.28	1.27	0.41	-8.34
250w/speed	mean	rms	sd	mean dif	%rms
oper	0.36	4.53	4.51		
eclev	0.13	4.33	4.32	-0.23	-4.54
eculev	0.10	4.30	4.30	-0.26	-5.00
VWE250/m/s	mean	rms	sd	mean dif	%rms
oper	5.14	6.37	3.74		
eclev	4.93	6.12	3.62	-0.21	-3.87
eculev	4.99	6.15	3.59	-0.16	-3.40
		TABLE 2.2			

TABLE 2.2 summarises the mean scores for all the parameters over the whole period. Whilst the general improvements to pressure and upper level scores are somewhat smaller than for the earlier period, there is little degradation from using the thinner bottom layer.

2. 3 COMPARISON OF ECULEV AND OPERATIONAL -PERIOD 08/06/94 UNTIL 28/07/94

The revised 31 levels, eculev, was run for a longer period until 27/07/94. TABLE 2.3 summarises the mean scores for the whole period from these forecasts and the operational forecasts. The improvements to rms upper wind errors are 2.5-3% and are only about half the size of the earliest period 15/05/94-08/06/94. Similarly, surface pressure and 250hPa temperature error reductions are less. There appears to be a seasonal effect that as the magnitude of the errors is reduced in moving to summer the impact of the extra resolution is less.

3. SUBJECTIVE ASSESSMENT -PERIOD OF TRIAL 14TH MAY - 7TH JUNE 1994

3.1 INTRODUCTION

The limited area model was rerun daily during this period from DT00Z using increased vertical resolution plus a longer timestep (15 minutes) for the physics. The trial forecasts with increased vertical resolution ran directly from a reconfiguration of the operational limited area analysis and boundary files. Since the early stages of the trial forecasts may have been affected by the reconfiguration, the assessment concentrated on the later stages, i.e. T+18 onwards.

The subjective assessment consisted of a three way comparison between the following versions:

(a) Operational 19 level LAM:
(b) 31 level LAM (same as mesoscale model levels with 15 levels in boundary layer) plus a 15 minute timestep for physics:
(c) 31 level LAM (same as ECMWF model levels with 7 levels in the boundary layer and increased vertical resolution around the jets) plus a 15 minute timestep for physics.

For convenience, the forecasts described above will be referred to as operational, meslevs and eclevs respectively in the subjective assessment.

3.2 SUBJECTIVE ASSESSMENT.

Increased vertical resolution had little impact upon forecast evolution, although there were small differences in detail. Trial depressions over the sea varied by +/- 4mb but over land, trial depressions tended to be slightly less deep. Mean sea level pressure was slightly higher overland generally in the trial forecasts.

It was soon apparent that the amount of low cloud was resolution dependent. In particular, meslevs had a very marked impact upon low cloud and convection. The overall impression gained from the three weeks of the meslevs forecasts was;

(a) low cloud increasing steadily throughout the forecast;

Mean results 08/06/94-28/07/94, whole LAM area					
T850/K	mean	rms	sd	mean dif	%rms
oper	-0.29	1.22	1.18		
eculev	-0.37	1.29	1.23	-0.08	5.57
H500/m	mean	rms	sd	mean dif	%rms
oper	-2.83	13.61	13.13		
eculev	-3.40	13.98	13.36	-0.57	2.70
PMSL/Pa	mean	rms	sd	mean dif	%rms
oper	-0.78	171.13	168.32		
eculev	-1.43	168.63	165.61	-0.64	-1.46
T250/K	mean	rms	sd	mean dif	%rms
oper	-0.49	1.39	1.30		
eculev	0.00	1.29	1.29	0.49	-6.99
250w/speed	mean	rms	sd	mean dif	%rms
oper	0.16	4.27	4.26		
eculev	-0.05	4.13	4.13	-0.21	-3.11
VWE250/m/s	mean	rms	sd	mean dif	%rms
oper	4.87	6.04	3.57		
eculev	4.76	5.90	3.48	-0.12	-2.42
		TABLE 2.3			

(b) even when correctly forecast, the predicted cloud base was too low and amounts sometimes excessive;

(c) slight reduction in the amount of light rain predicted over the sea due to retention of moisture as low cloud;

(d) weaker convection associated with increased low cloud resulting in fewer showers overland;

(e) in clearer areas, however, showers could be heavier.

Eclevs showed the above features but to a smaller extent. The following case studies illustrate the above points.

3.3 Case Examples

a) DT 00Z 12/05/94

The operational forecast for T+18, **Figure 3.1b**, predicted a band of showers on a weak occlusion over Northern England and the North Midlands. Although there had been rain from the occlusion earlier in the day, it had mostly died out by 18Z as the radar, **Figure 3.1a**, confirms. The meslevs forecast, **Figure 3.1c**, predicting only isolated showers, was better.

At T+36, both the operational and meslevs forecasts, (**Figures 3.2 b and c**), predicted instability on the site of the old weak occlusion, but these showers were spurious as indicated by the radar, **Figure 3.2a**. A bigger difference was noticed between the forecast rainfall and low cloud over Germany and Poland. The operational forecast, **Figures 3.2b and 3.3a**, predicted widespread showers but little layer cloud. This was in contrast to the meslevs forecast, **Figures 3.2c and 3.3b,** which predicted a cloudy afternoon with fewer showers. The observations in **Figure 3.4** indicate that the operational showers were too widespread, whilst the low cloud predicted by the meslevs forecast was excessive.

This was the first meslevs forecast and it gave an early indication of low cloud increasing with time.

(b) DT 00Z 26/05/94

On 27th May, a ridge of high pressure extended across the British Isles from an anticyclone centred south of Iceland. The problem for forecasters was the extent and base of low cloud in the north-northeasterly airstream in the North Sea. The visual satellite images for 06Z and 12z, **Figures 3.5 a/b**, show an area of shallow cumulus/stratocumulus in the North Sea being advected westwards across Southern Scotland and Eastern England. The charts in **Figures 3.6 a/b/c** represent the low and medium cloud of amounts > 4 octas predicted at T+30 from the operational, meslevs and eclevs forecasts. The low cloud over the North Sea and east coast of Scotland and England was only predicted in the meslevs forecast.

The T+36 cloud forecasts are compared in **FIGURES 3.7 a/b/c**. Again, the low cloud forecast from the meslevs forecast was the best for predicting the low cloud over the east coast, although the operational and eclevs forecasts were both predicting the formation of low cloud inland. At 12Z, Hemsby was reporting 2 octas of cumulus at base 2,200 feet and 7 octas of stratocumulus at base 4700 feet. This cloud is represented in the Hemsby ascent for 11z, **FIGURE 3.8a**, with the main cloud just below the inversion at the top of the boundary layer. The predicted T+36 ascents for Hemsby from the operational, meslevs and eclevs forecasts are represented by **FIGURES 3.8 b/c/d**. Although the meslevs forecast was the only one to predict the low cloud over Hemsby correctly at T+36, the ascent, **FIGURE 3.8c**, was disappointing, with the cloud base too low (925-945hPa) and the inversion poorly represented. The meslevs cloud forecasts at T+30 and T+36, **FIGURES 3.6b and 3.7b**, show the increasing low cloud over the sea, which looked too extensive to the west of Scotland.

(c) DT 00Z 28/05/94

By midday on 29th May, scattered mainly light showers had developed over Northwest England, the Midlands and central Scotland as indicated by the radar image in **FIGURE 3.9a** and also by the visual satellite image in **FIGURE 3.9b**. The operational rainfall forecast for T+36, (Figure 3.10a), verifying at 12z, predicted the showers over England correctly but the forecast showers over Scotland were too far west and the forecast showers over Ireland were spurious. Neither of the trial versions, **FIGURES 3.10 b and c**, improved the forecast, both predicting showers to be too widespread over England as well as Ireland. The eclevs forecast was the worst in this respect.

Over the continent, the reverse was true, with the trial forecasts predicting fewer showers over eastern Germany and Poland, due to lower temperatures and increased low cloud. The truth was probably between the operational and trial forecasts. Some showers/thunderstorms were reported in this area at 12z with some layer cloud.

Comparing the three T+36 cloud forecasts in **FIGURES 3.11 a/b/c**, the increased low cloud in the trial forecasts, especially meslevs, was very noticeable over the sea as well as land. The increased cloud over England in the trial forecasts can probably be justified by observations. The visual satellite image for 12Z, **FIGURE 3.9b**, shows a good coverage of cloud over England, layer as well as convective, and observations over Northern England and the Midlands indicated broken stratocumulus at about 5000 feet. In **FIGURE 3.12**, the Aughton ascent for 12Z is compared with the T+36 forecast model ascents for Aughton. The meslev ascent, **FIGURE 3.12c**, is closest to the radiosonde ascent, **FIGURE 3.12a**, with some representation of the inversions at 900 and 730 hPa. Over the North Sea, the visual satellite image, **FIGURE 3.9b**. indicates mainly convective cloud and the low cloud predicted by the meslevs forecast, **FIGURE 3.13b**, was overdone. The three model T+36 forecast ascents for 55N 05E are compared in Figures 3.13 a/b/c. The meslevs forecast, **FIGURE 3.13b**, predicted layer cloud at 930hpa, the condensation level.

(d) DT 00Z 04/06/94

At 12Z 5th June, the visual satellite image, **FIGURE 3.14a**, shows increasing cloud from a warm front moving into Ireland, settled conditions over the U.K. and convective cells developing over the North Sea and the continent. The T+36 cloud predictions from the operational, meslevs and eclevs forecasts, **FIGURES 3.15 a/b/c**, show characteristic differences, with the meslevs predicting excessive low cloud. In particular, the low cloud predicted over Western Scotland and Northwest England by the operational and meslevs forecasts was misleading, as most places had a dry,sunny day under the influence of a ridge of high pressure. Judging from the Aughton ascent for 12Z, **FIGURE3.14b**, we would only expect shallow cumulus at low levels. The model T+36 forecast ascents for Aughton are compared in **FIGURES 3.16 a/b/c**. The base of the low cloud predicted by the operational and meslevs forecasts was 3000 feet which was correct but the amount of cloud excessive. Over the north sea, the northwesterly airstream was still unstable and the visual satellite image, **FIGURE3.14a**, shows only convective cloud. The meslev prediction of low cloud was overdone. The three model T+36 forecast ascents for 55N 05E are compared in **FIGURES 3.17 a/b/c**. Again the meslevs forecast over-predicted the amount of cloud at 900hpa, the condensation level.

3.4 SUBJECTIVE CONCLUSIONS

1. No changes in forecast evolution. Depressions overland slightly less deep.

2. Increasing the vertical resolution in the boundary layer led to increased low cloud being predicted.

3. The increased low cloud was often an accurate indication of the presence of low cloud, but the predicted cloud base was too low and amounts often excessive.

4. Increased vertical resolution led to some improvement in boundary layer structure but this was not consistent.

5. With increased vertical resolution, the forecast distribution of showers tended to be less widespread due to increased low layer cloud. The increase of low layer cloud in unstable airmasses was misleading, although the reduction of showers was sometimes better. In clearer areas, however, showers could be heavier.

6. There was a slight reduction in the amount of light rain predicted over the sea due to retention of moisture as low cloud.

4. CONCLUSIONS

The conclusion from verification against analyses was that it was more advantageous

to increase resolution in the free atmosphere and at jet level than in the boundary layer. Upper level winds and temperatures verified better at T+24. With the mesoscale levels there was a larger cold bias at 850hPa and worse 500hPa height errors. The cooling was due to increased low cloud which the subjective assessment found to be too low and at times excessive.

These trials showed the potential improvement that could be gained from extra vertical resolution. For a full assessment the final 31 levels set (eculev) was tested using the parallel suite in the forecast global model configuration. This was run in July 1994 and showed a worsening of the lower atmosphere cold bias and degradation of 500hPa height verification (see **Technical report 114**, Wilson and Hammon, 1994). Further work is necessary to investigate the cause of increased cloud and amend the model physics to perform more realistically with the new levels before operational implementation.

REFERENCES

Wilson C A , O M Hammon and R T H Barnes, 1994:
Trials of a longer timestep for physics in the limited area model. *FR Technical Report **111***

Wilson C A and O M Hammon , 1994
Trial of increased vertical resolution in the global model. *FR Technical Report **114***

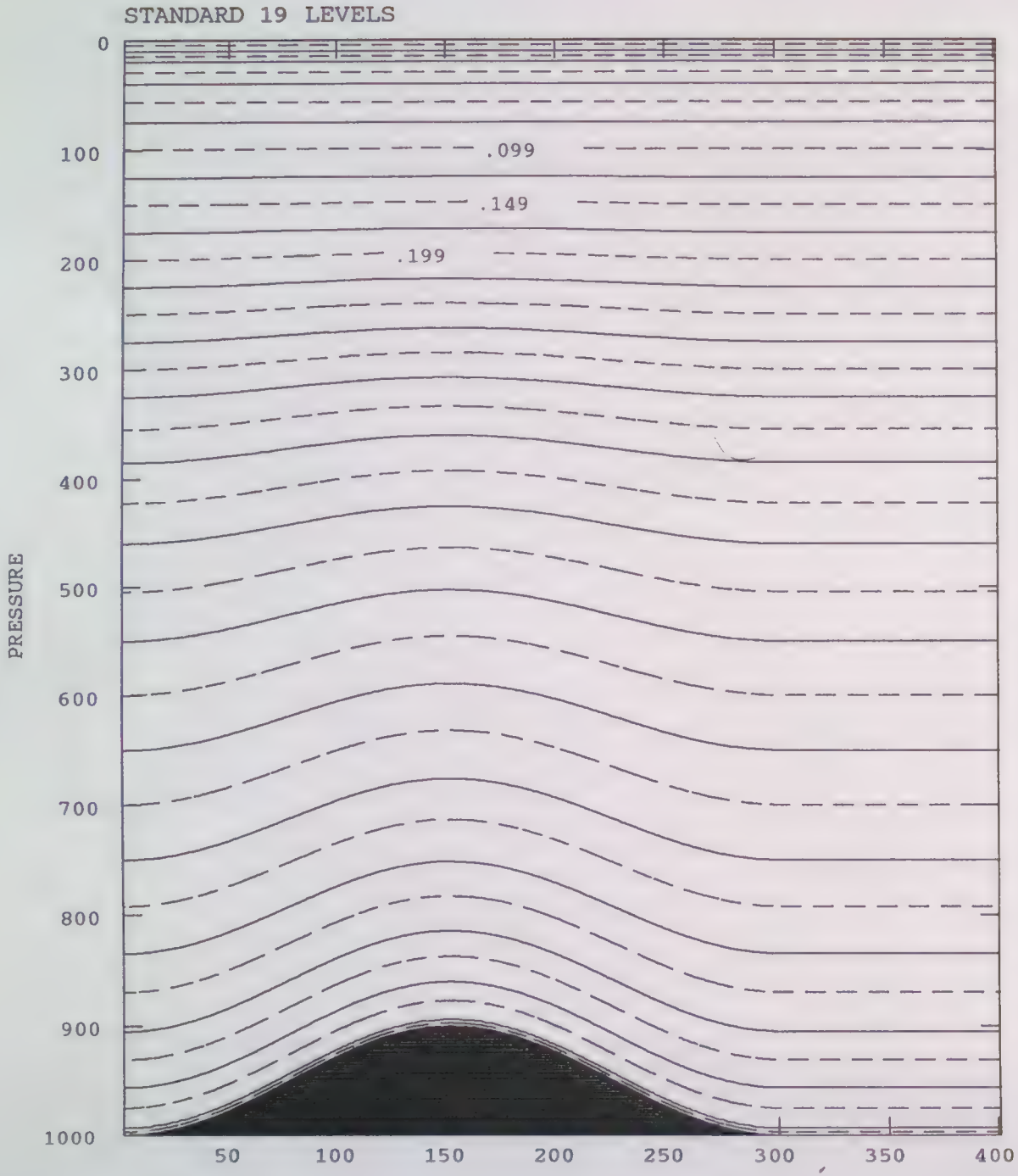

STANDARD 19 LEVELS
0
100
200
300
400
500
600
700
800
900
1000
PRESSURE
.099
.149
.199
50
100
150
200
250
300
350
400

FIGURE 1.1

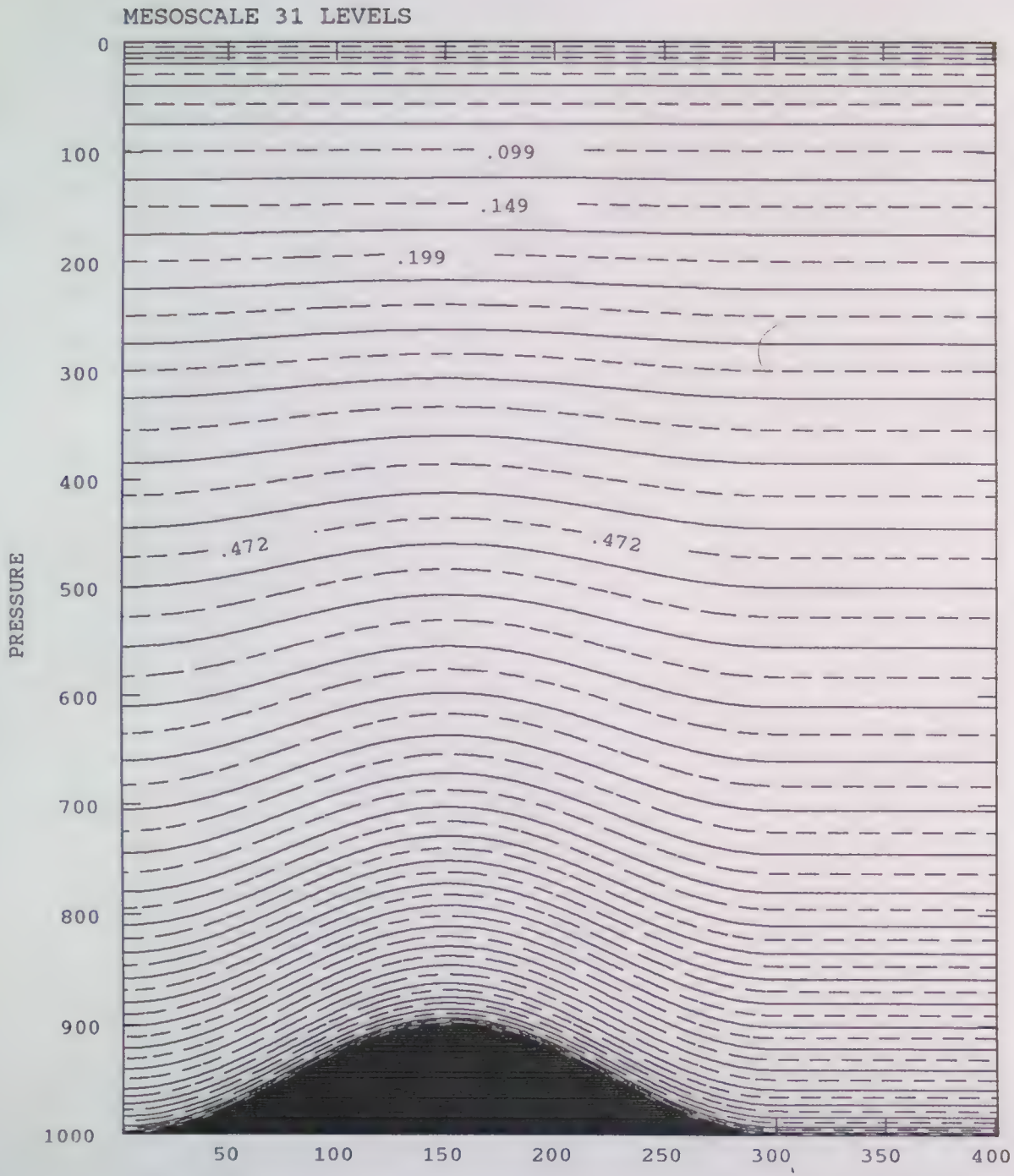

MESOSCALE 31 LEVELS
PRESSURE
0
100
200
300
400
500
600
700
800
900
1000
.099
.149
.199
.472
.472
50
100
150
200
250
300
350
400

FIGURE 1.2

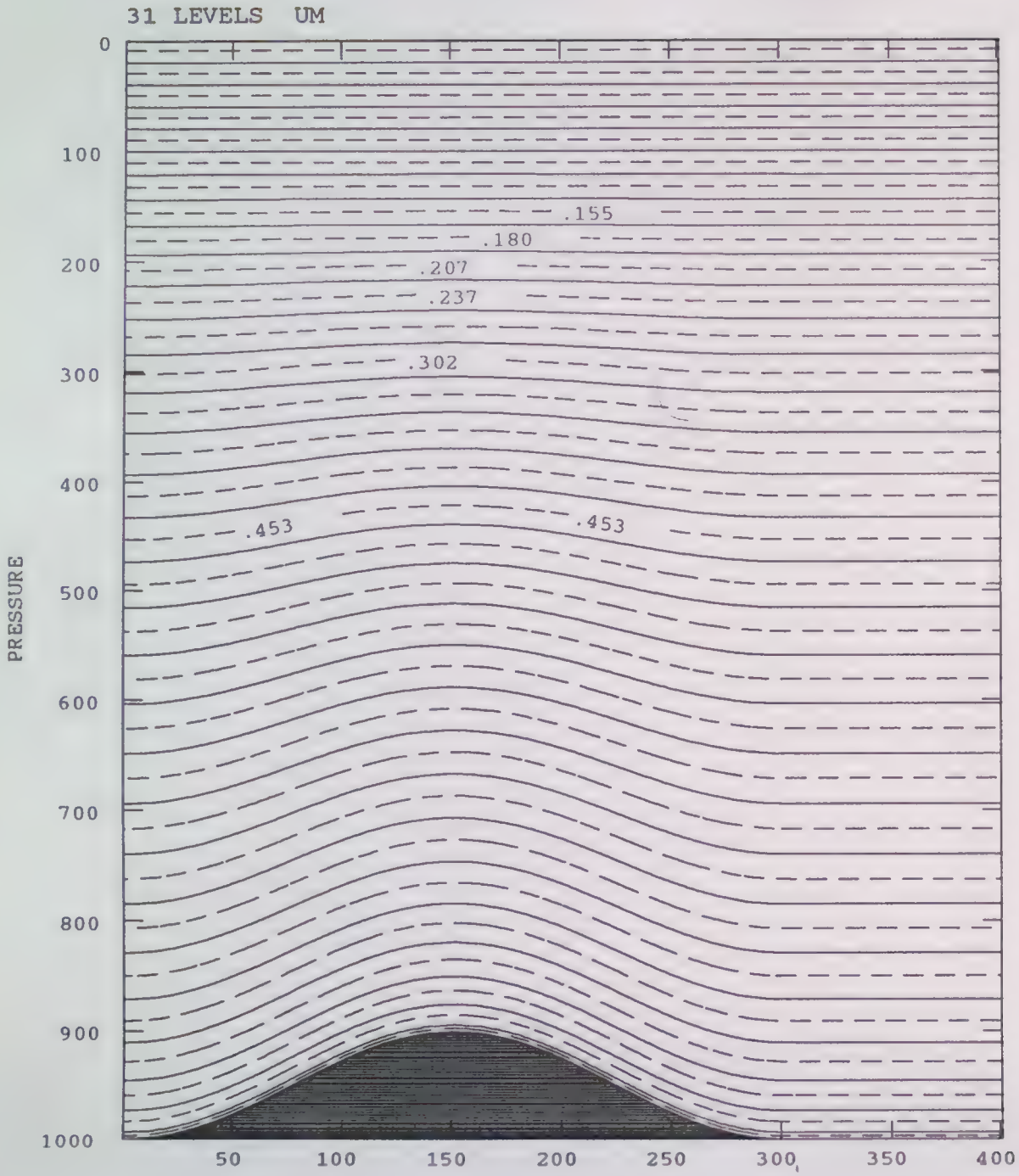

31 LEVELS UM
PRESSURE
0
100
200
300
400
500
600
700
800
900
1000
.155
.180
.207
.237
.302
.453
.453
50
100
150
200
250
300
350
400

FIGURE 1.3

250hPa VECTOR WIND VERIFICATION AGAINST ANALYSES T+24

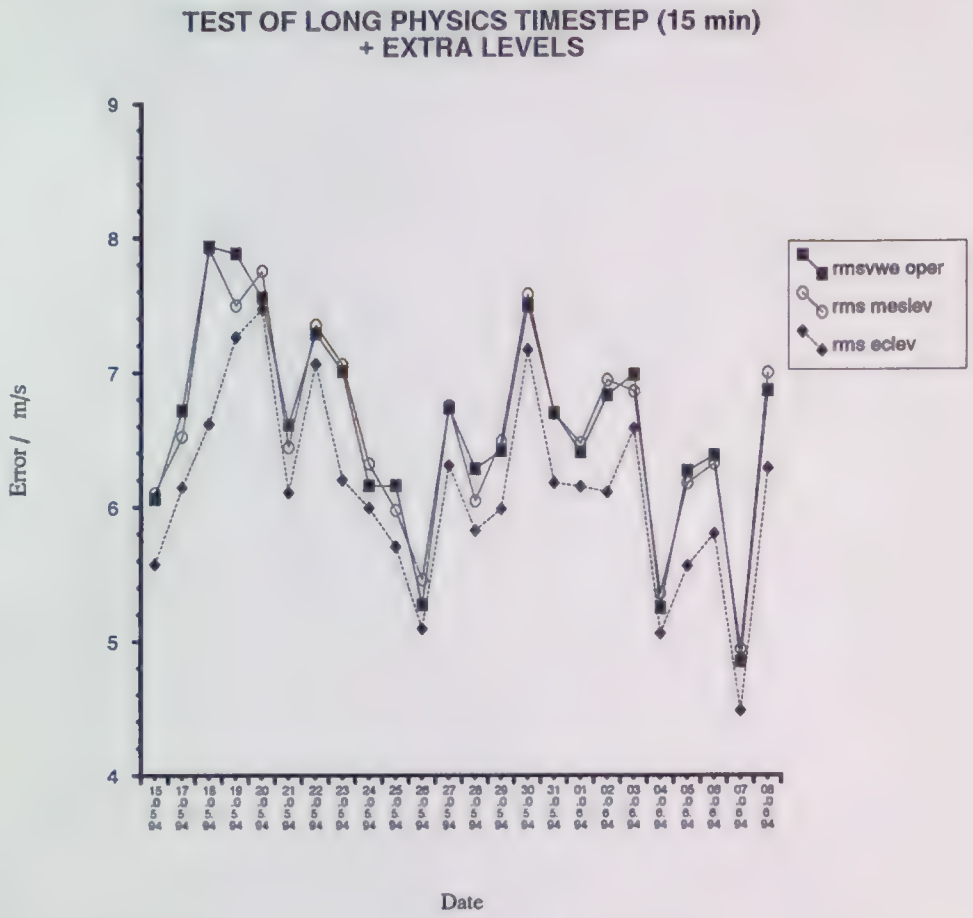


Fig 2.1

250hPa WIND SPEED VERIFICATION AGAINST ANALYSES T+24

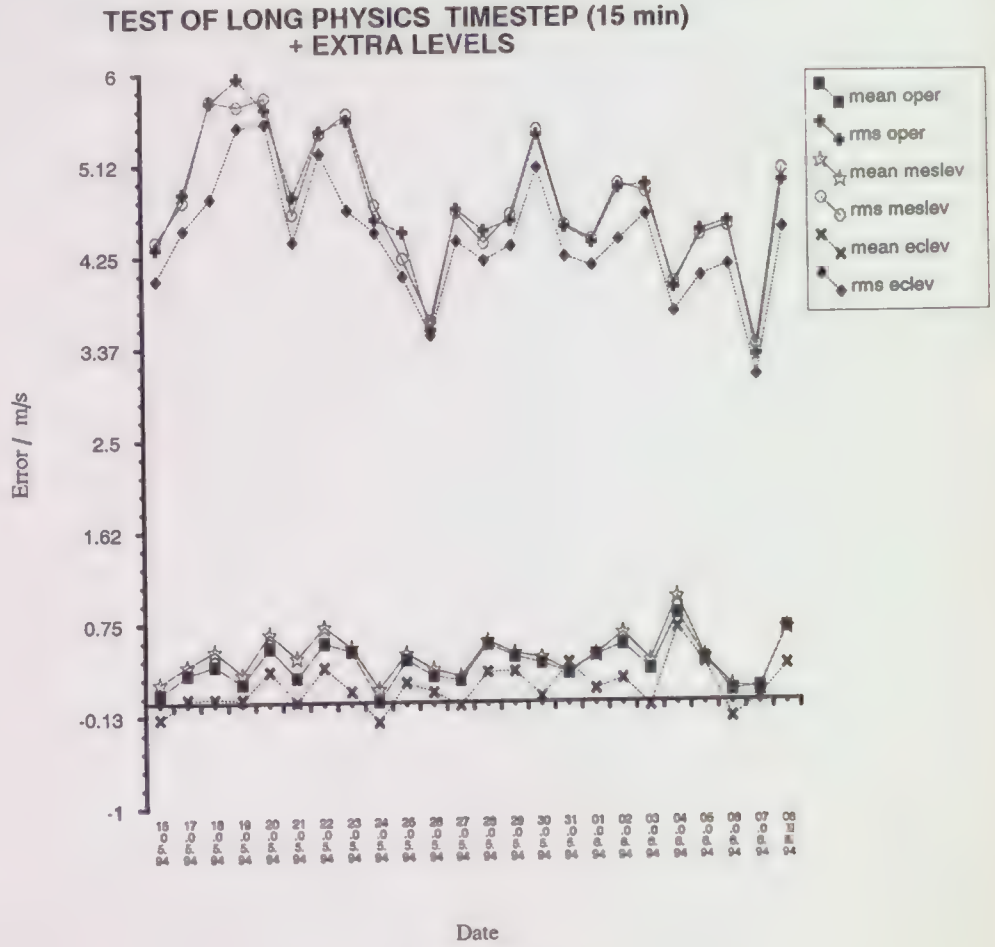


Fig 2.2

250hPa TEMPERATURE VERIFICATION AGAINST ANALYSES T+24

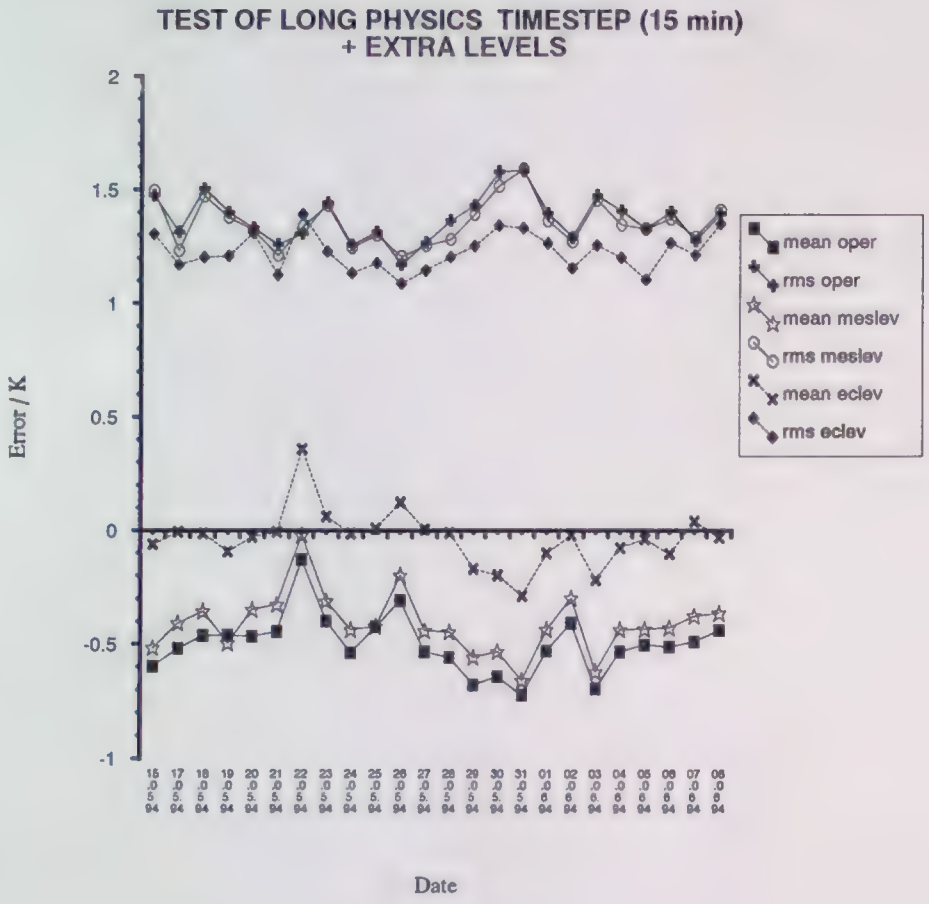


Fig 2.3

850hPa TEMPERATURE VERIFICATION AGAINST ANALYSES T+24

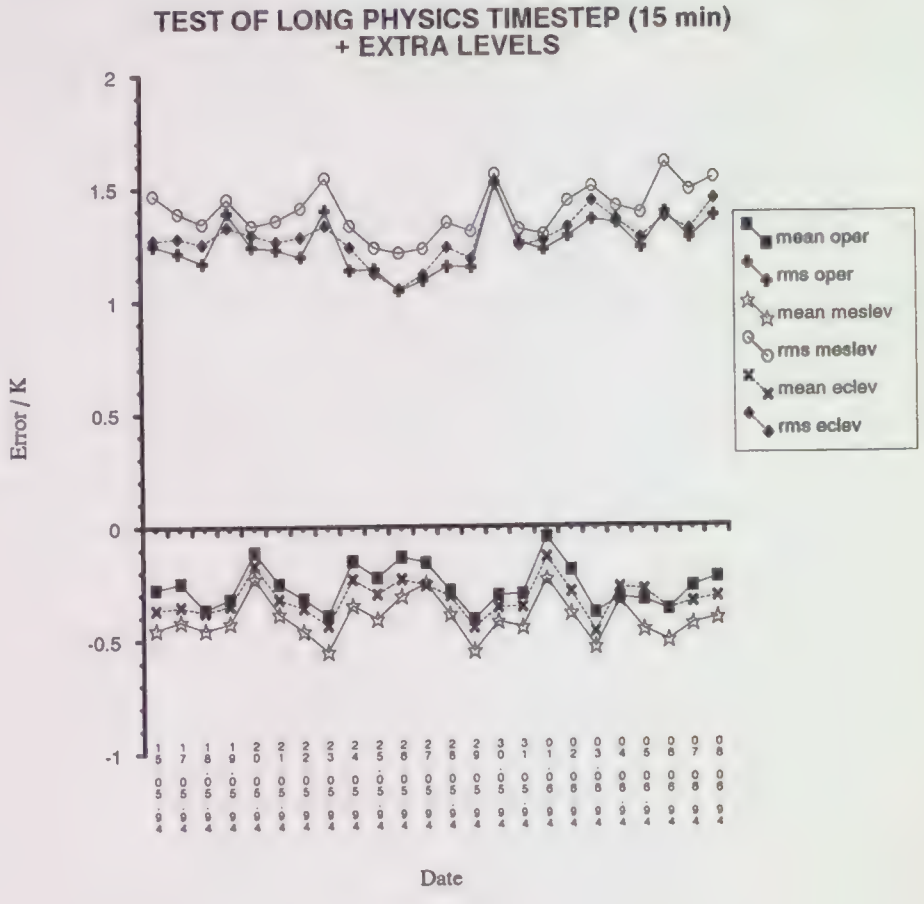


Fig 2.4

H500 VERIFICATION AGAINST ANALYSES T+24

TEST OF LONG PHYSICS TIMESTEP (15 min)
+ EXTRA LEVELS

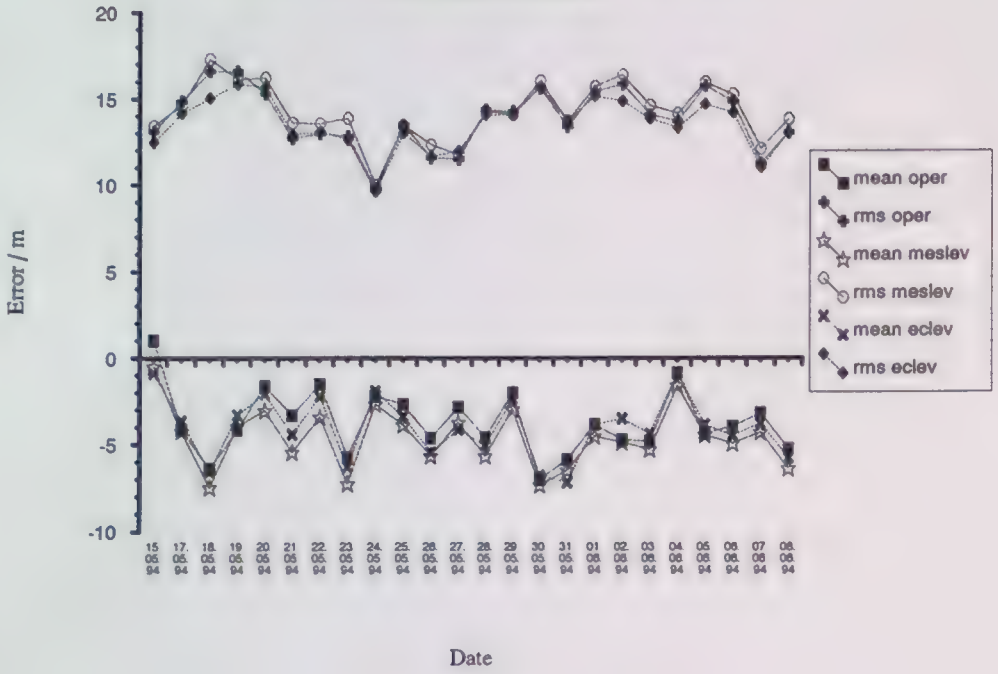


Fig 2.5

PMSL VERIFICATION AGAINST ANALYSES T+24

TEST OF LONG PHYSICS + ASSIMILATION TIMESTEP (15 min)
+ EXTRA LEVELS

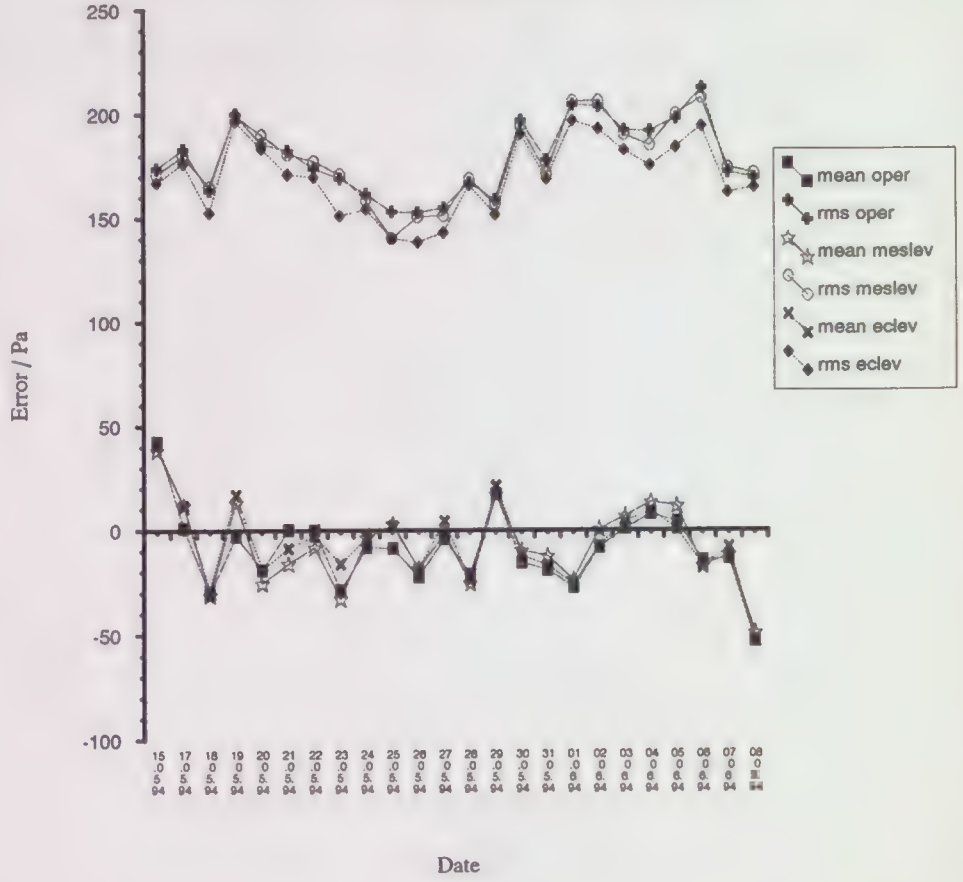
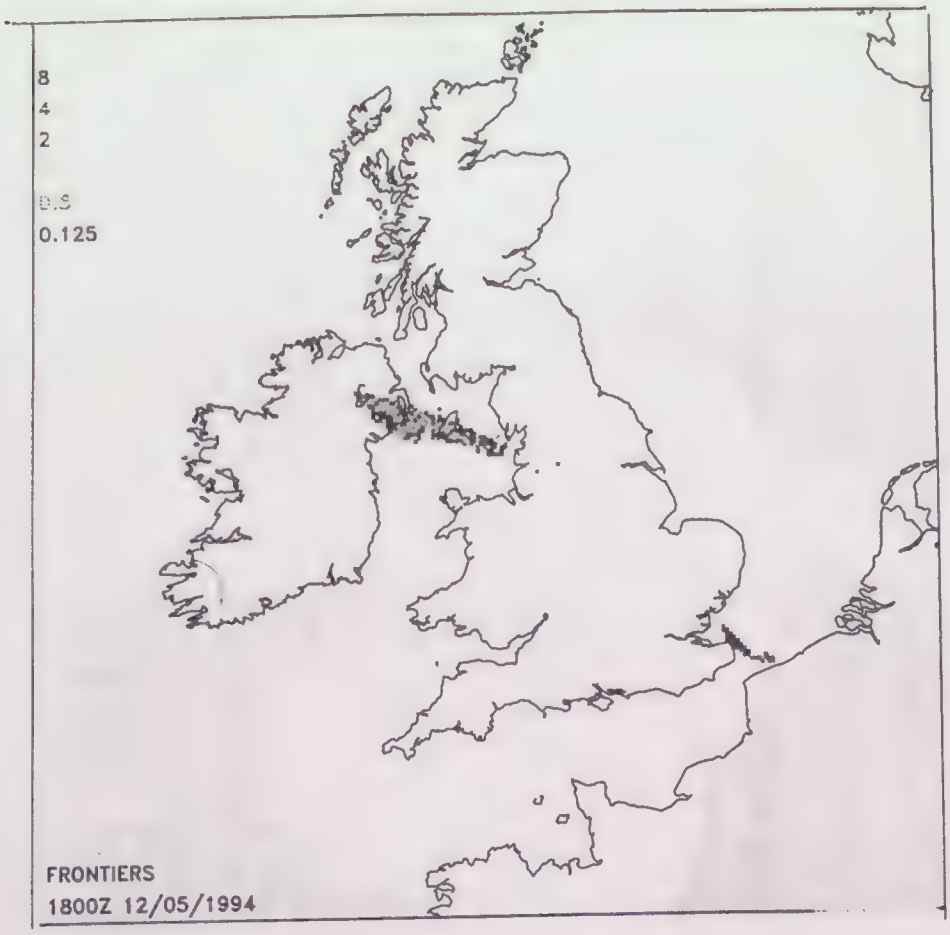
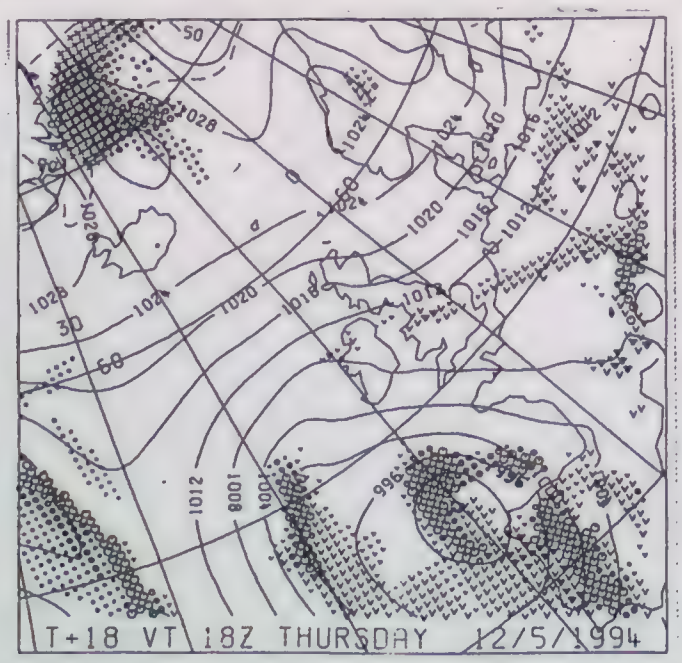


Fig 2.6

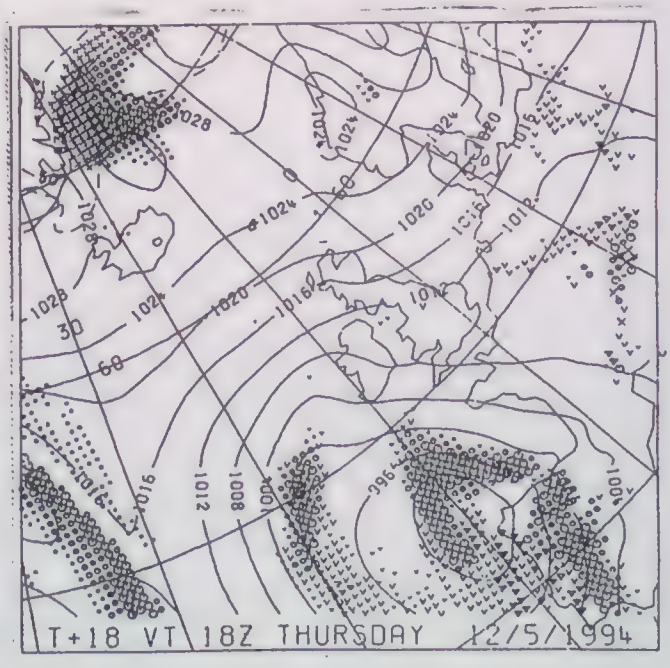
FIGURE 3.1



a Radar for 18z 12/05/94



b

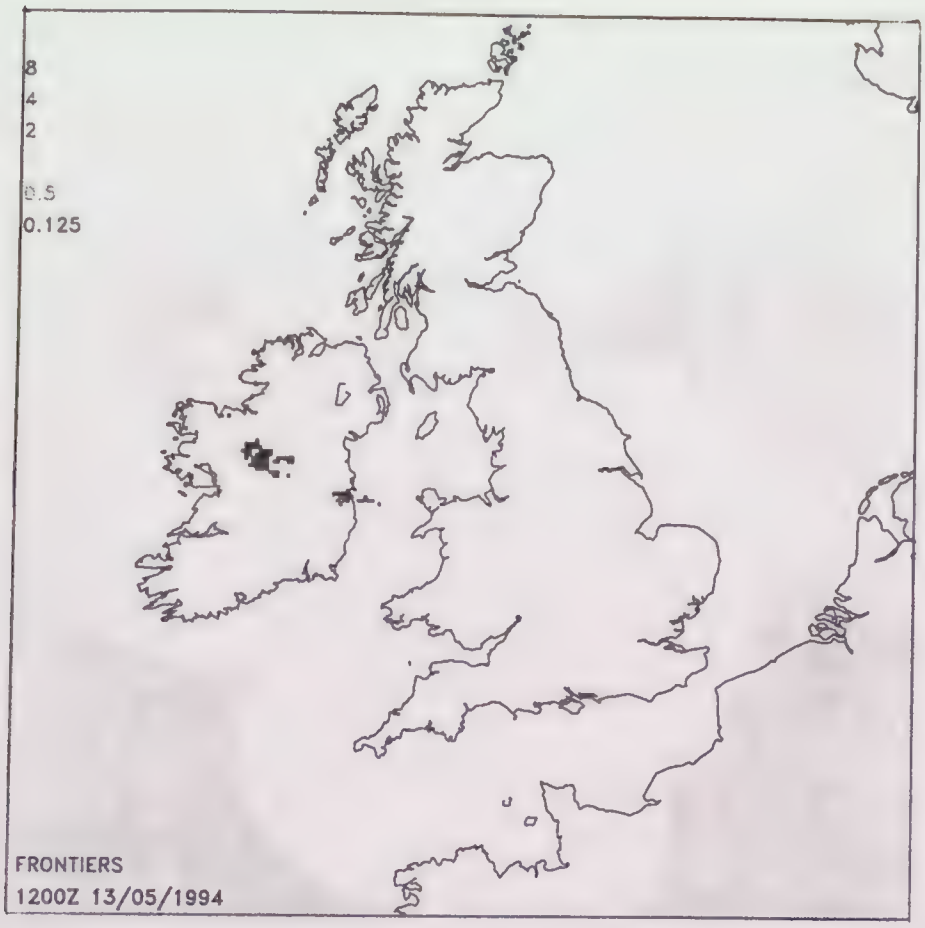


c

Total rainfall rate T+18 verifying 18z 12/05/94
(b) operational (c) 31 levels (meslevs)

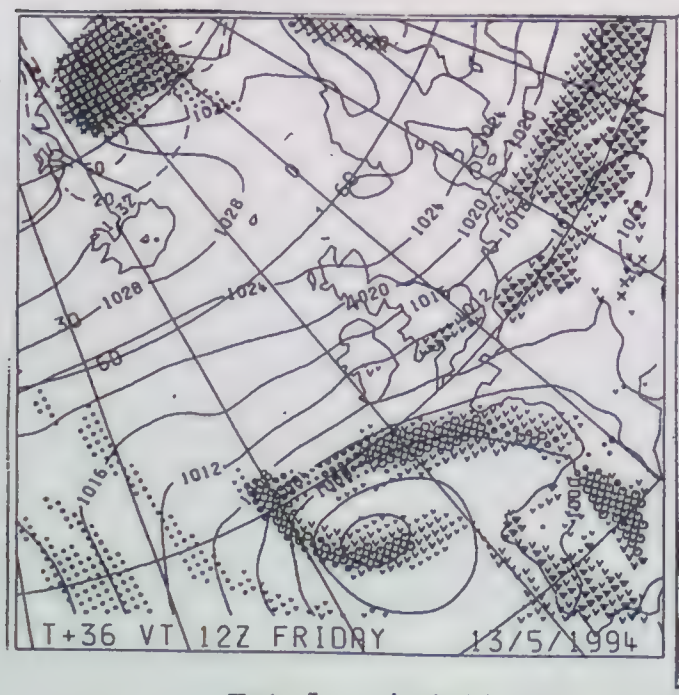
FIGURE 3.2

a

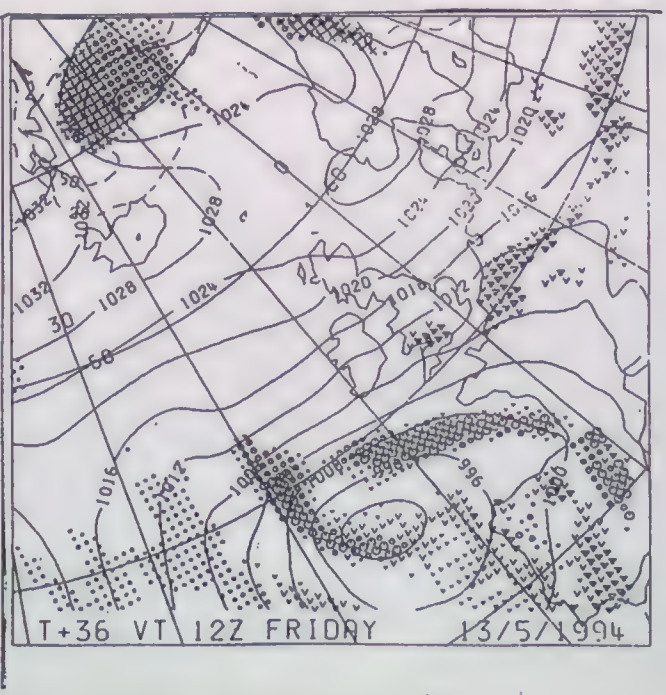


Radar for 12z 13/05/94

b



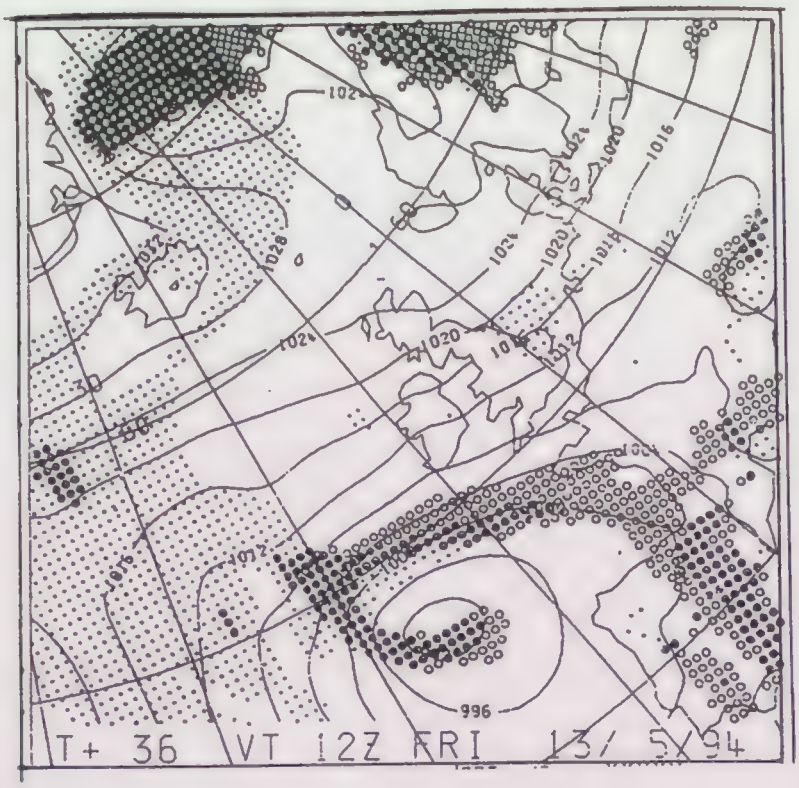
c



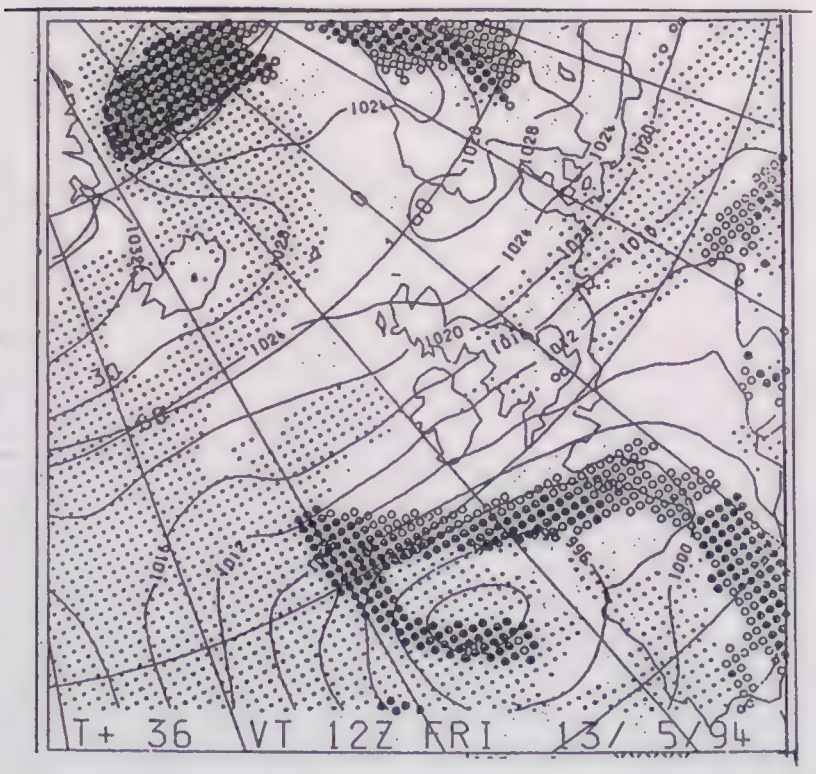
Total rainfall rate T+36 verifying 12z 13/05/94
(b) operational (c) 31 levels (meslevs)

FIGURE 3.3

a



b



T+36 cloud forecast verifying at 12z 13/05/94
o->4 octas medium cloud .->4 octas low cloud
(a) operational (b) 31 levels (meslevs)

FIGURE 3.4

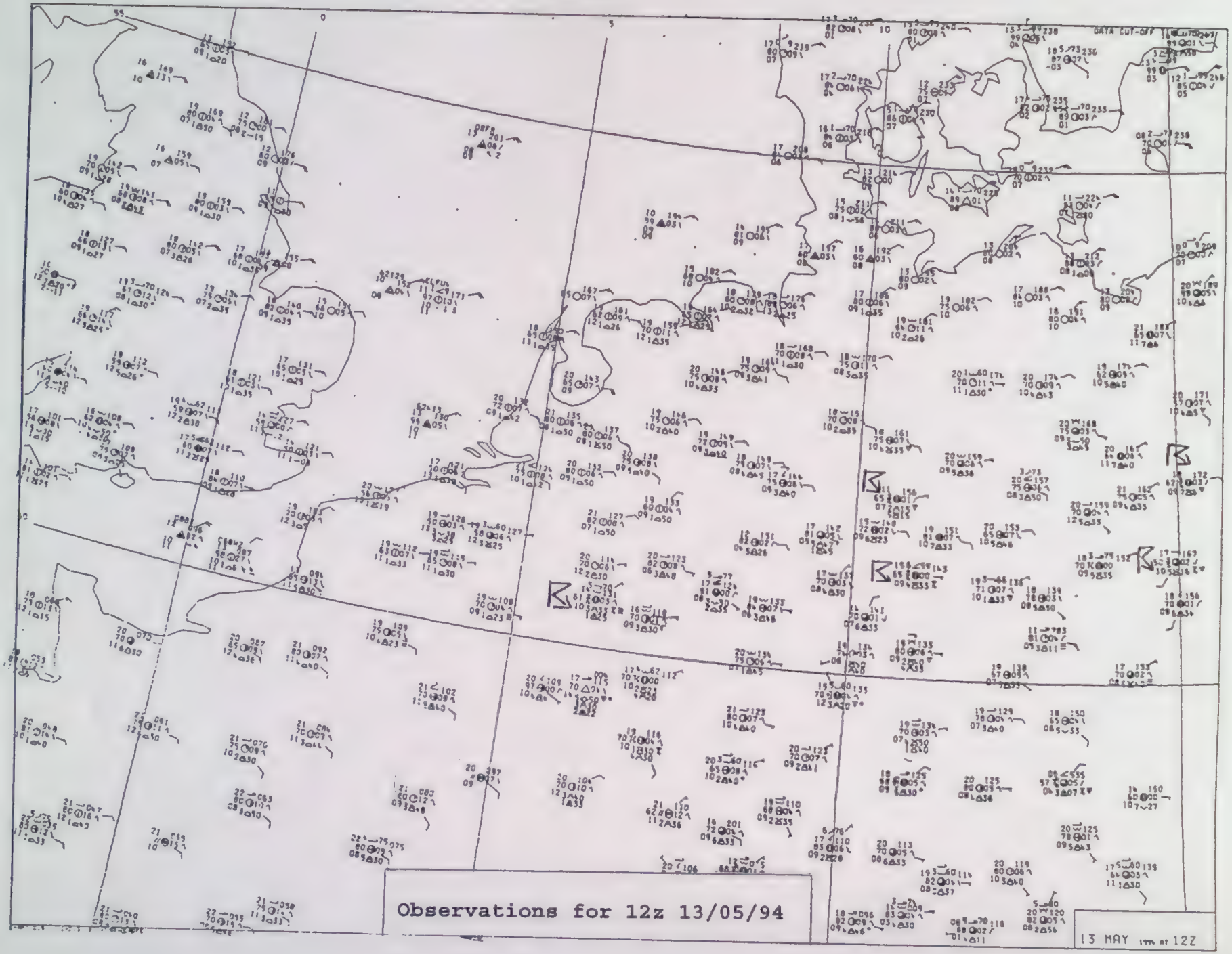
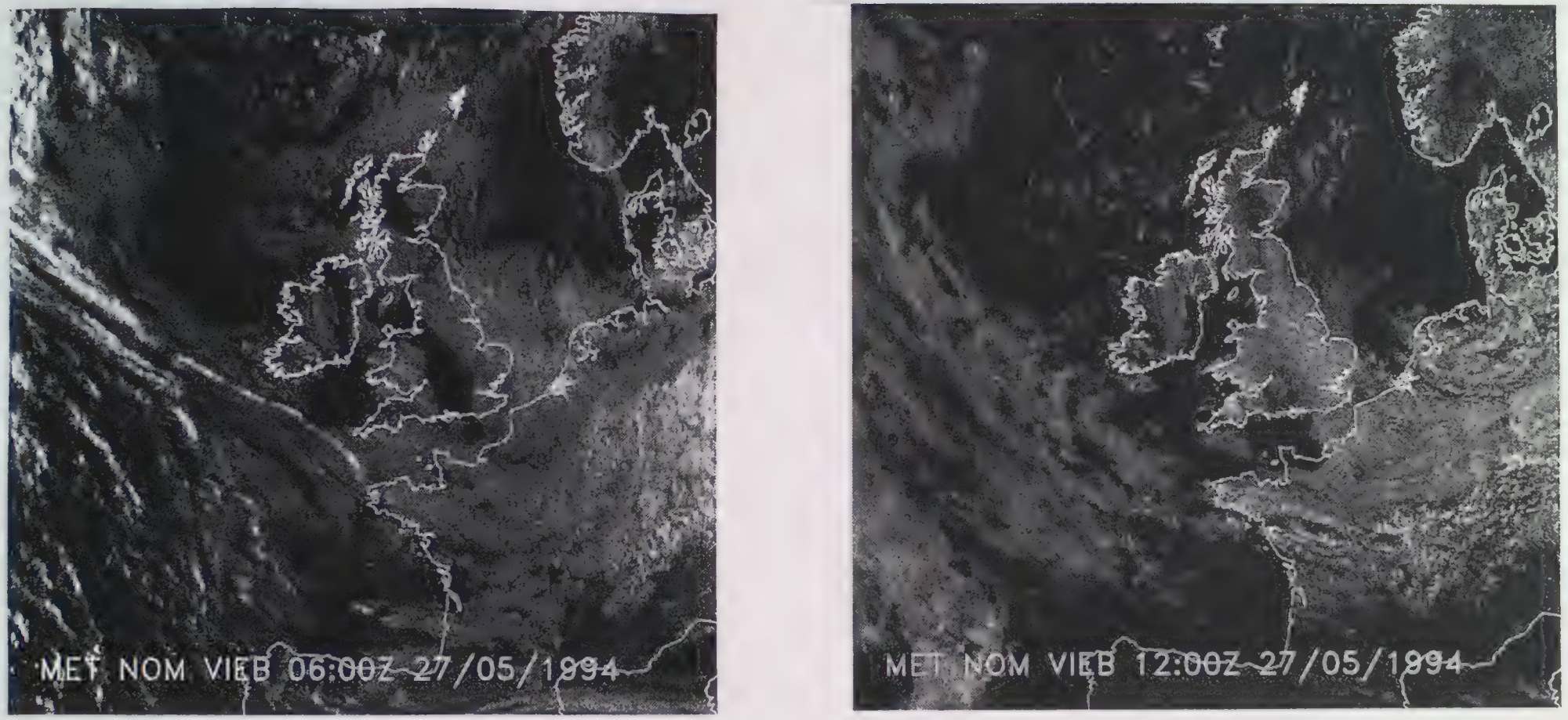


FIGURE 3.5



a b

Visual Satellite imagery
(a) 0600z 27/05/94 (b) 1200z 27/05/94

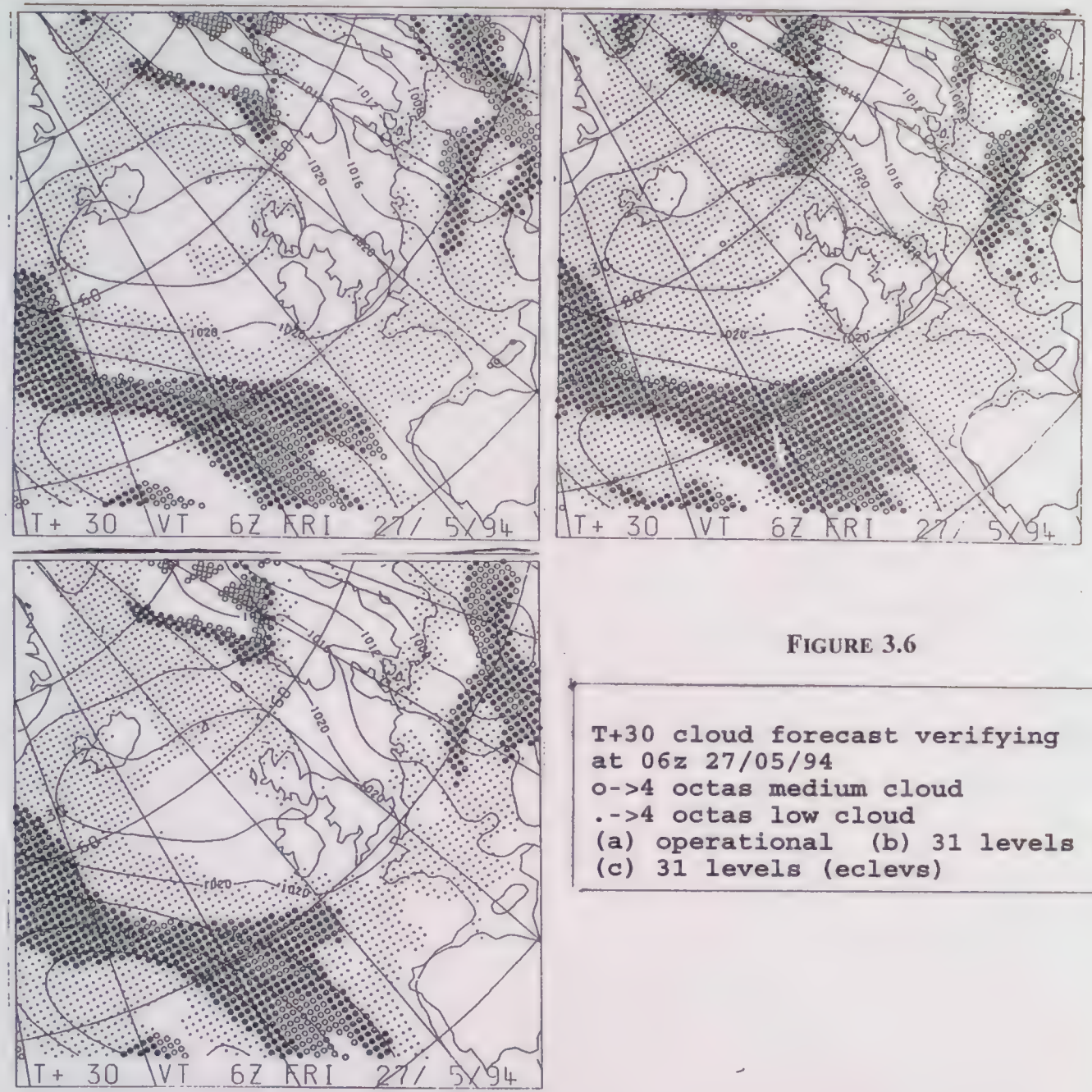
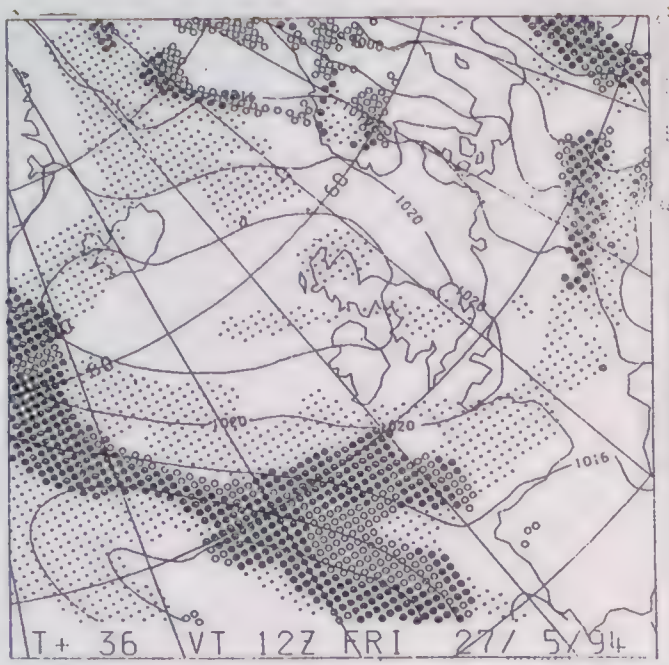
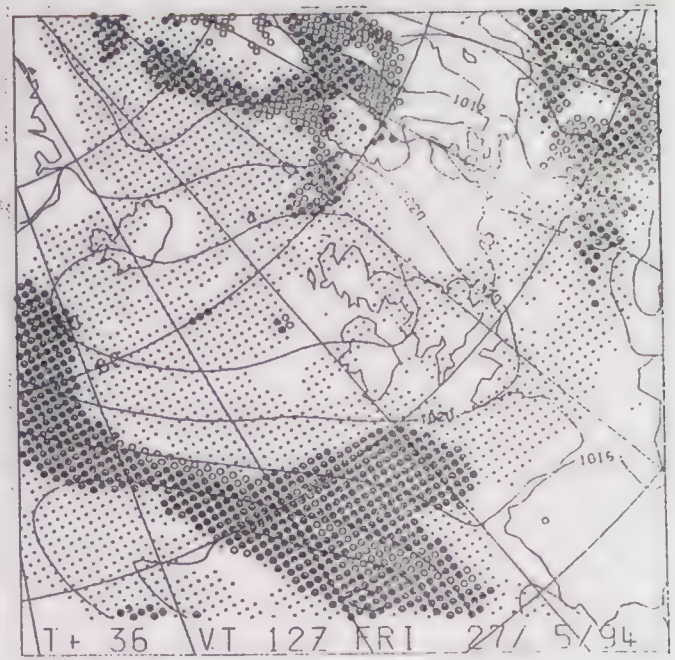


FIGURE 3.6

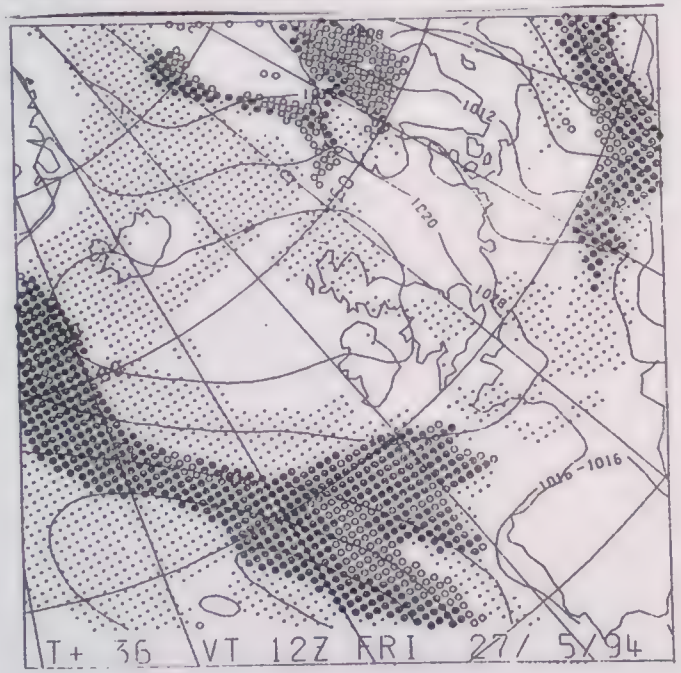
T+30 cloud forecast verifying
at 06z 27/05/94
o->4 octas medium cloud
.->4 octas low cloud
(a) operational (b) 31 levels (meslevs)
(c) 31 levels (eclevs)



a



b

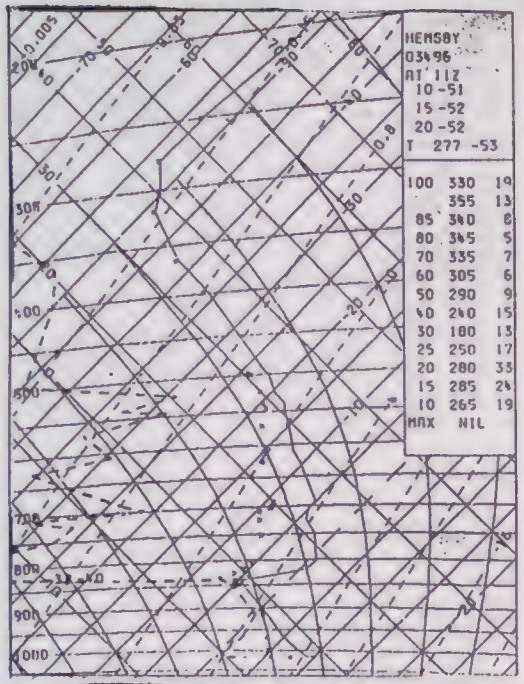


c

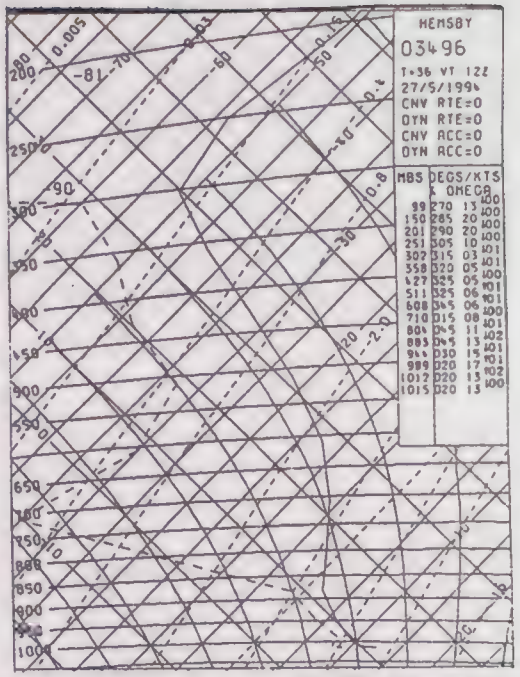
FIGURE 3.7

T+36 cloud forecast verifying
at 12z 27/05/94
o->4 octas medium cloud
.->4 octas low cloud
(a) operational (b) 31 levels (meslevs)
(c) 31 levels (eclevs)

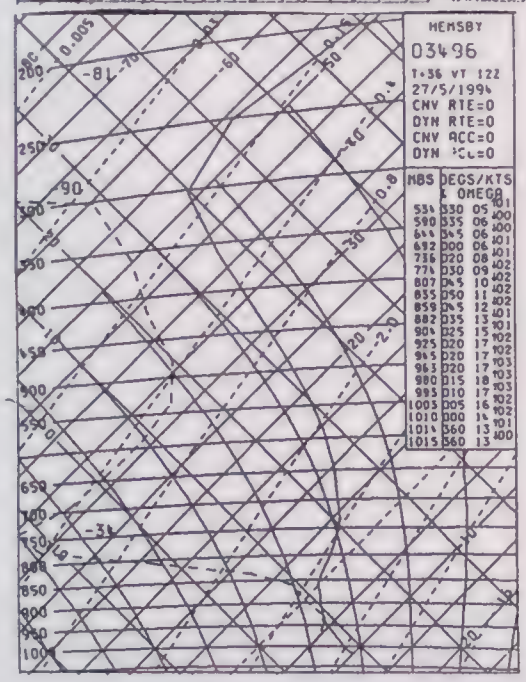
FIGURE 3.8



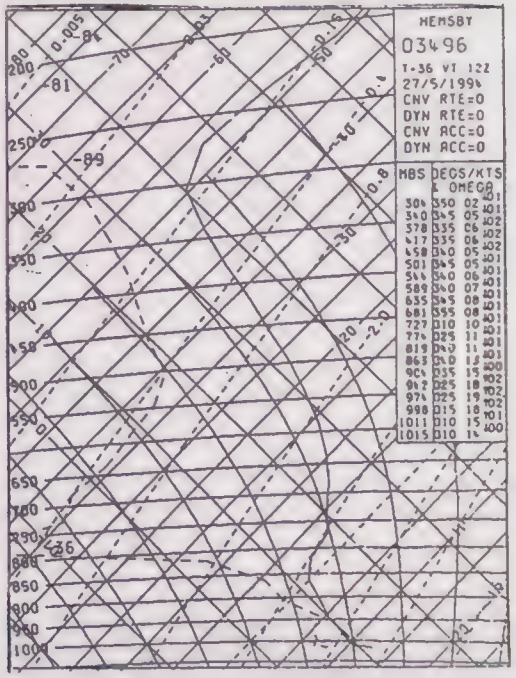
(a) Radiosonde ascent Hemsby 11z 27/05/94 obs cloud 2/8Cu 2200 7/8Sc 4700



(b) Oper f/c T+36 ascent for Hemsby VT 12z 27/05/94



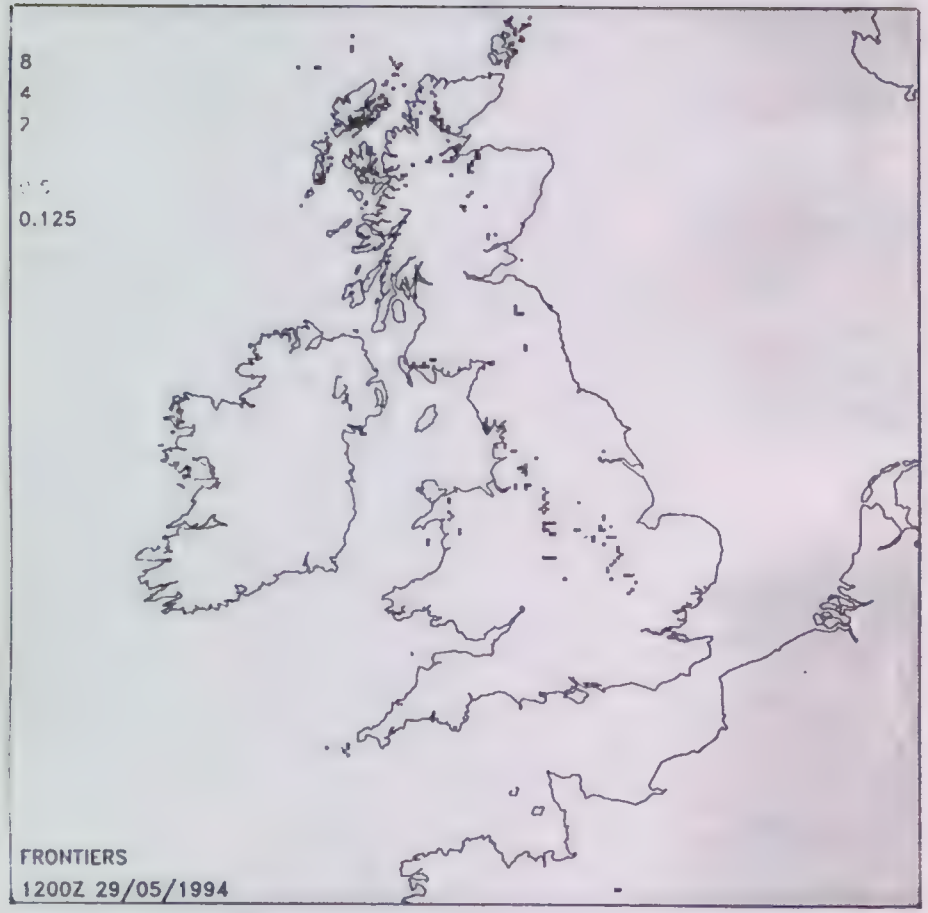
(c) Meslevs f/c T+36 ascent for Hemsby VT 12z 27/05/94



(d) Eclevs f/c T+36 ascent for Hemsby VT 12z 27/05/94

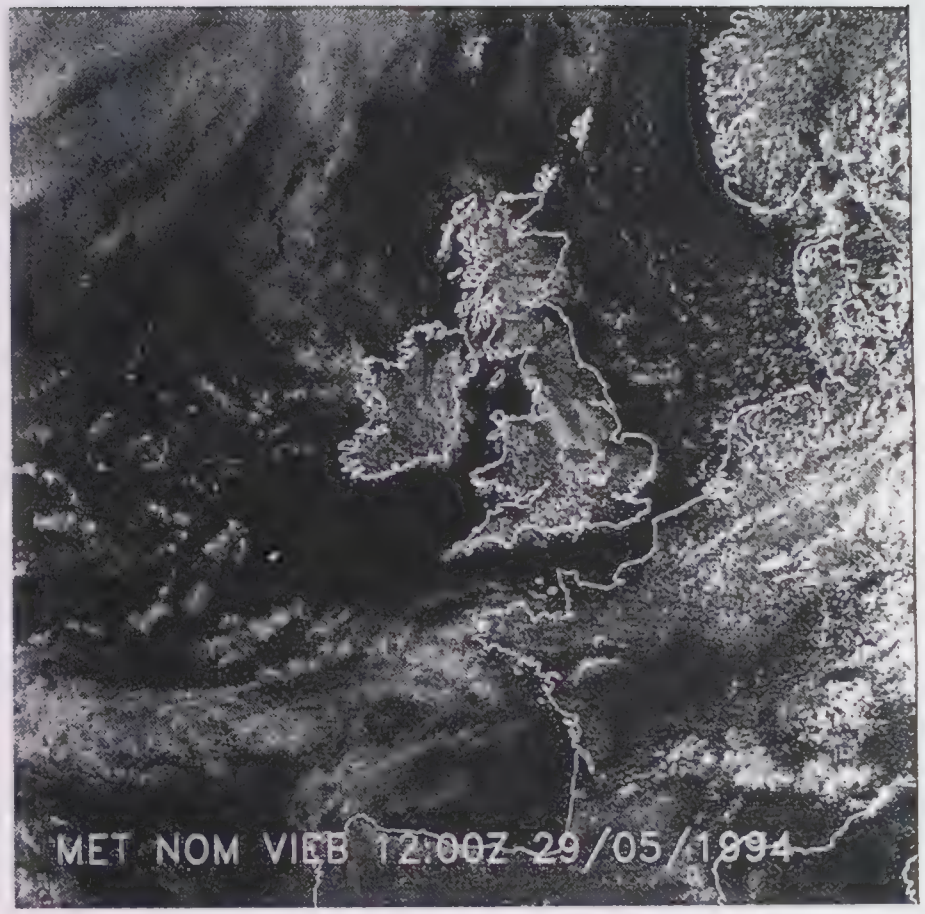
FIGURE 3.9

a



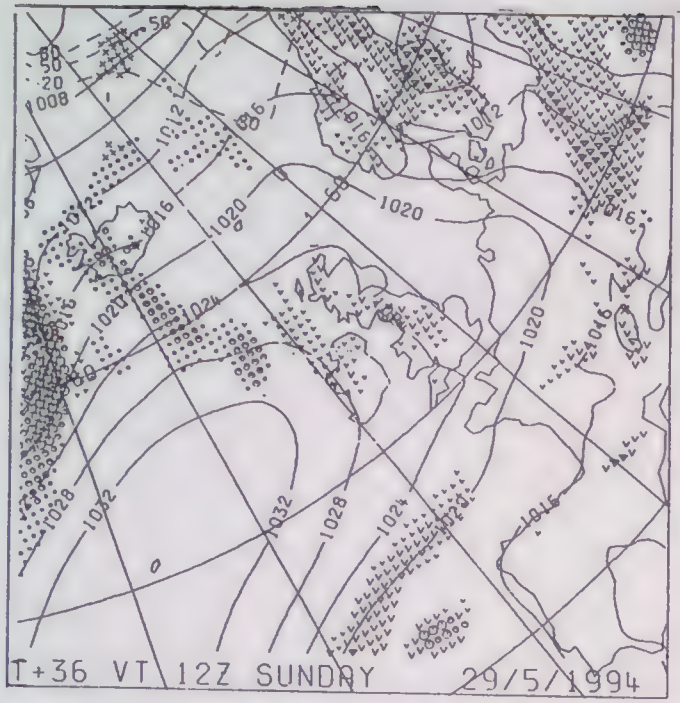
Radar for 12z 29/05/94

b

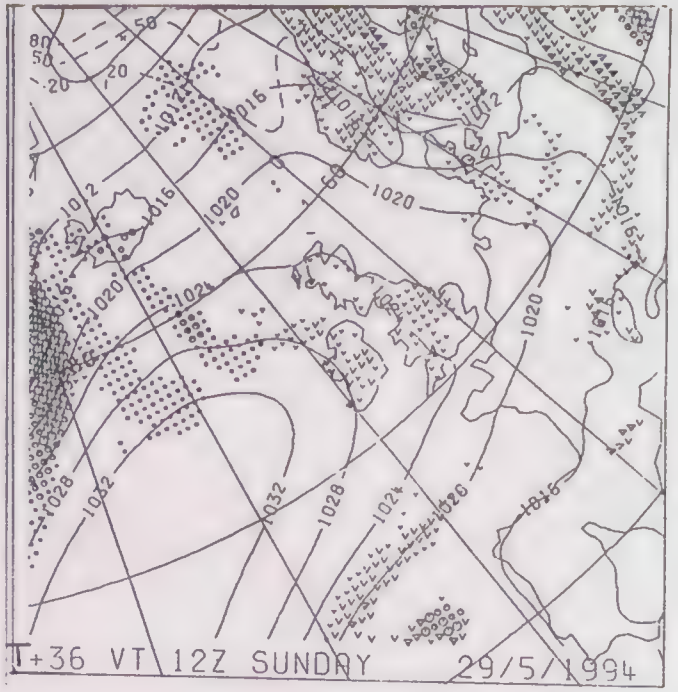


Visual satellite imagery
for 12z 29/05/94

a



b



c

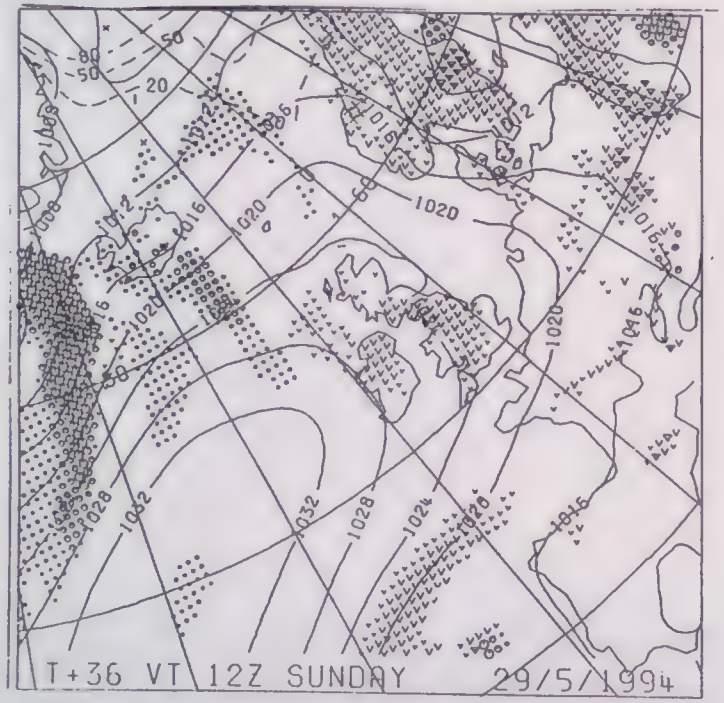
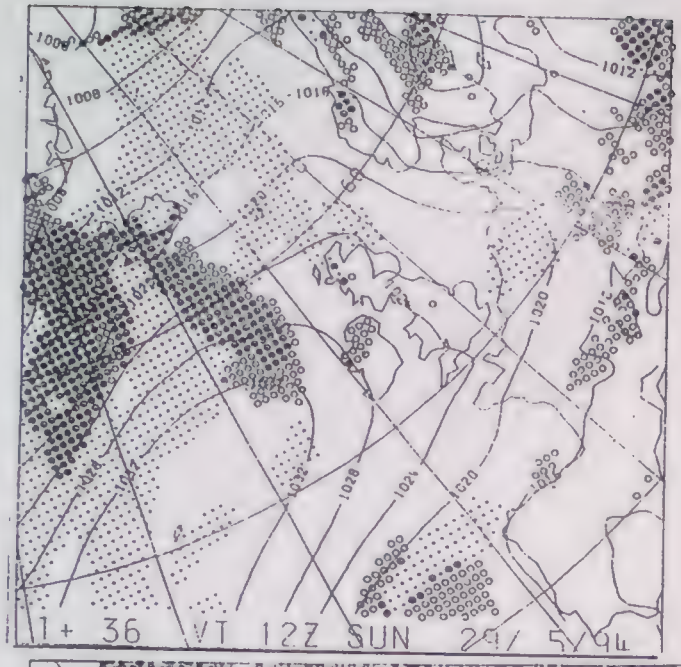


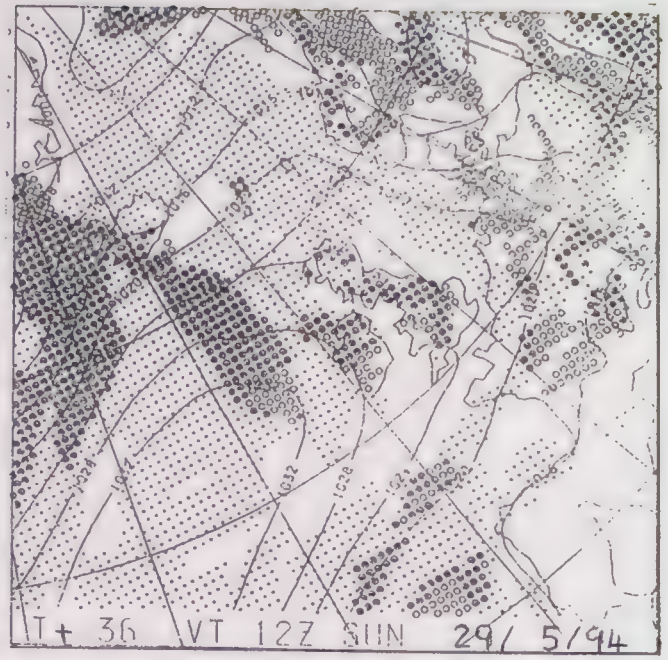
FIGURE 3.10

Total rainfall rate T+36
verifying 12z 29/05/94
(a) operational
(b) 31 levels (meslevs)
(c) 31 levels (eclevs)

a



b



c

FIGURE 3.11

T+36 cloud forecast verifying
at 12z 29/05/94
o->4 octas medium cloud
.->4 octas low cloud
(a) operational (b) 31 levels (meslevs)
(c) 31 levels (eclevs)

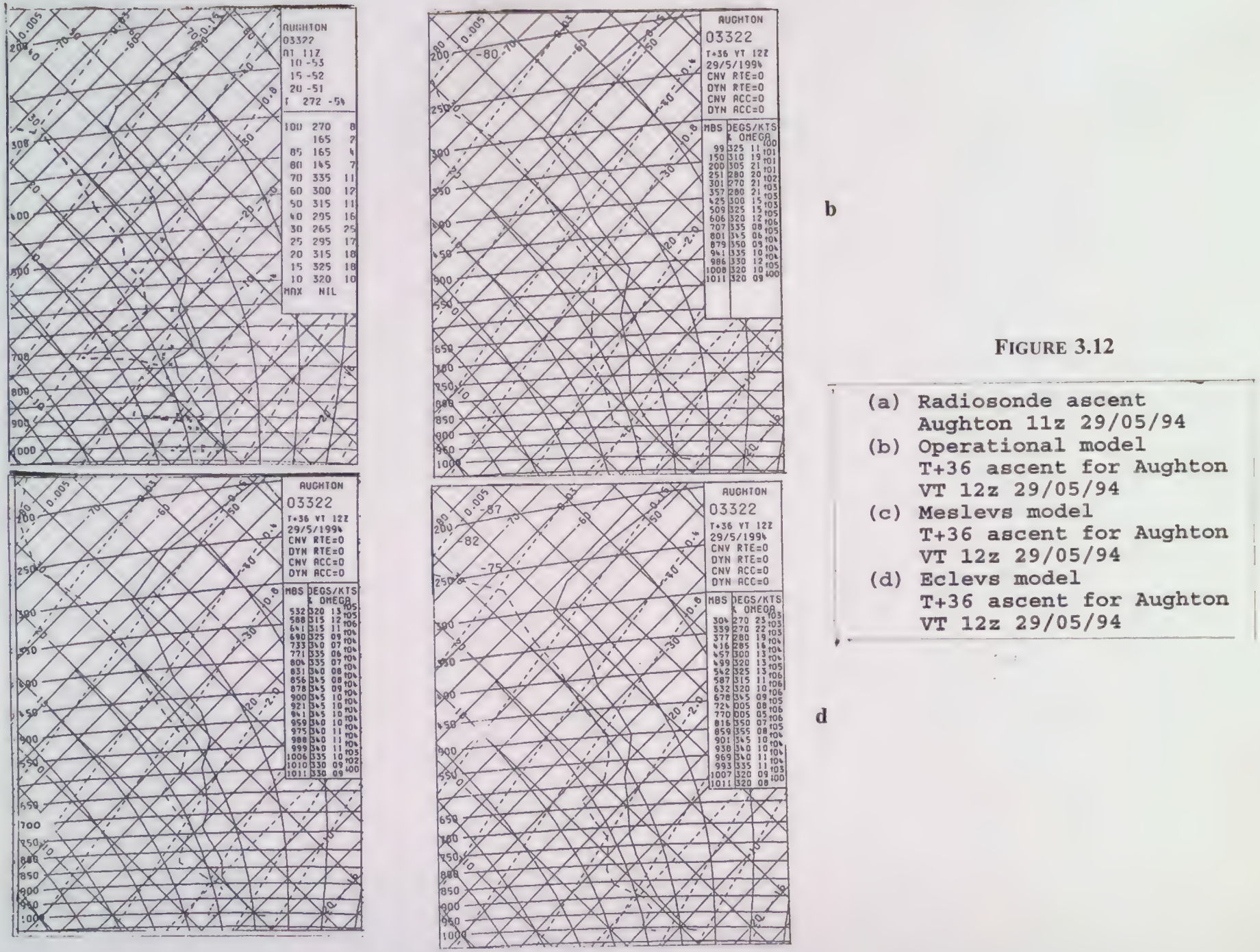
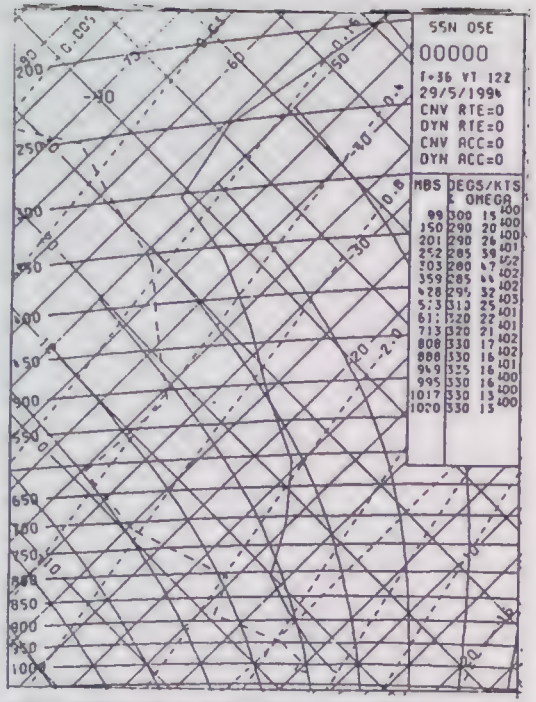


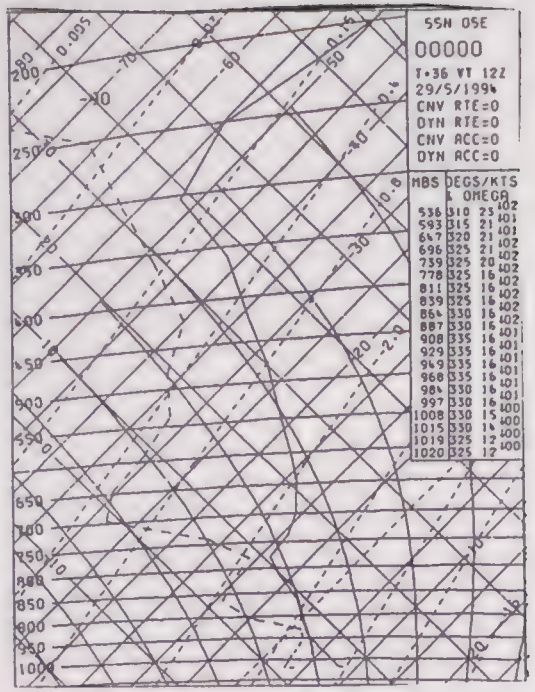
FIGURE 3.12

(a) Radiosonde ascent
Aughton 11z 29/05/94
(b) Operational model
T+36 ascent for Aughton
VT 12z 29/05/94
(c) Meslevs model
T+36 ascent for Aughton
VT 12z 29/05/94
(d) Eclevs model
T+36 ascent for Aughton
VT 12z 29/05/94

a



b



c

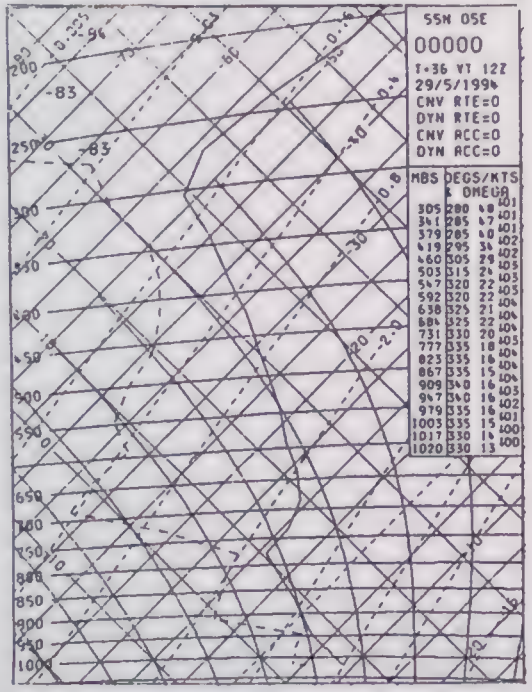
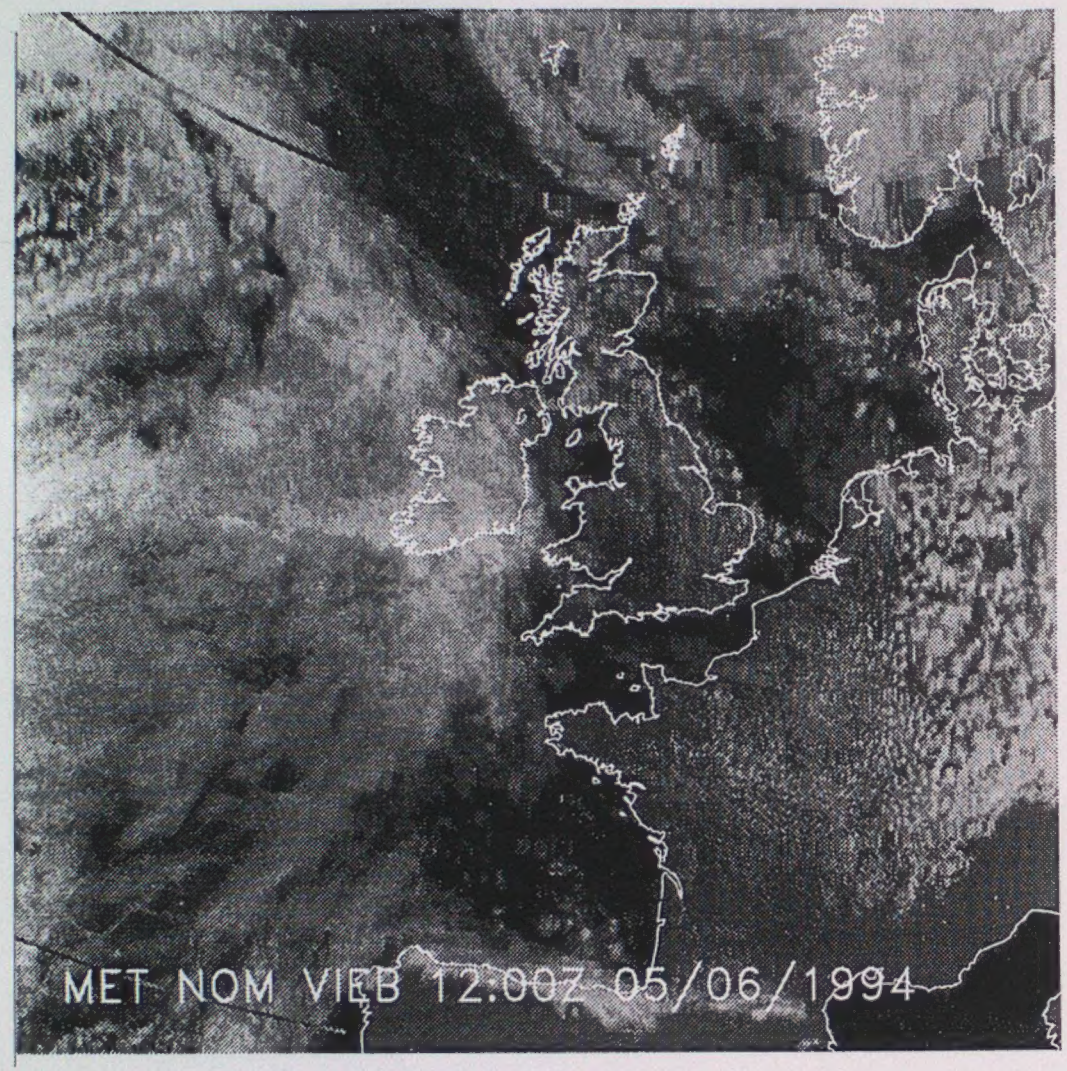


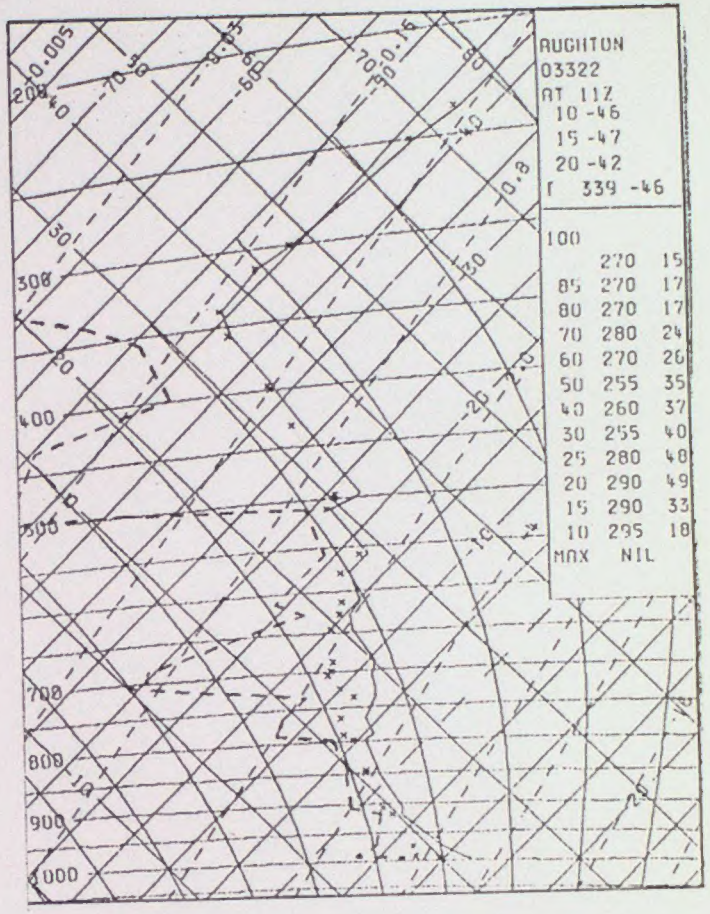
FIGURE 3.13

Model forecast ascents
T+36 ascent for 55N 05E
VT 12z 29/05/94
(a) Operational
(b) Meslevs
(c) Eclevs

FIGURE 3.14



a

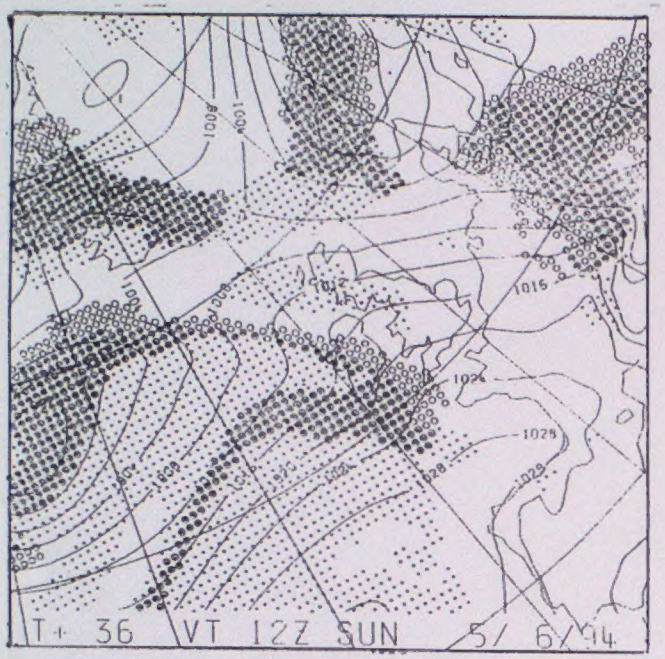


b

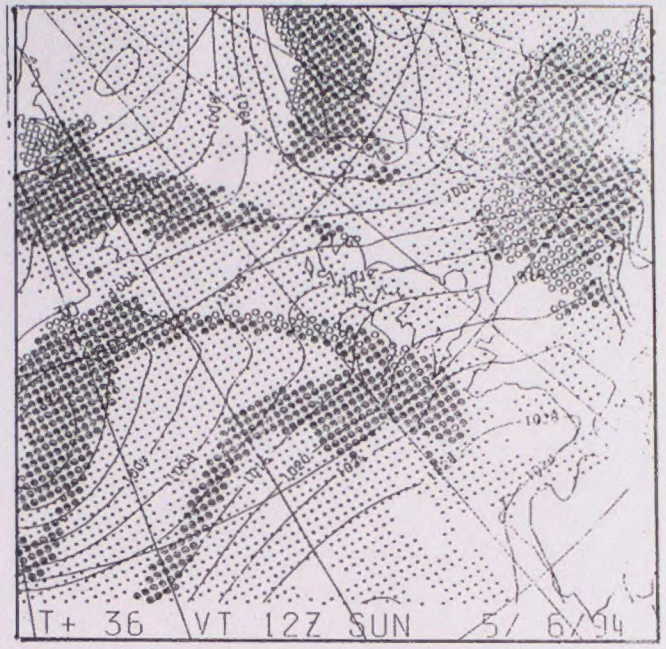
(a) Visual satellite image 12z 05/06/94

(b) Radiosonde ascent for Aughton 11z 05/06/94

a



b



c

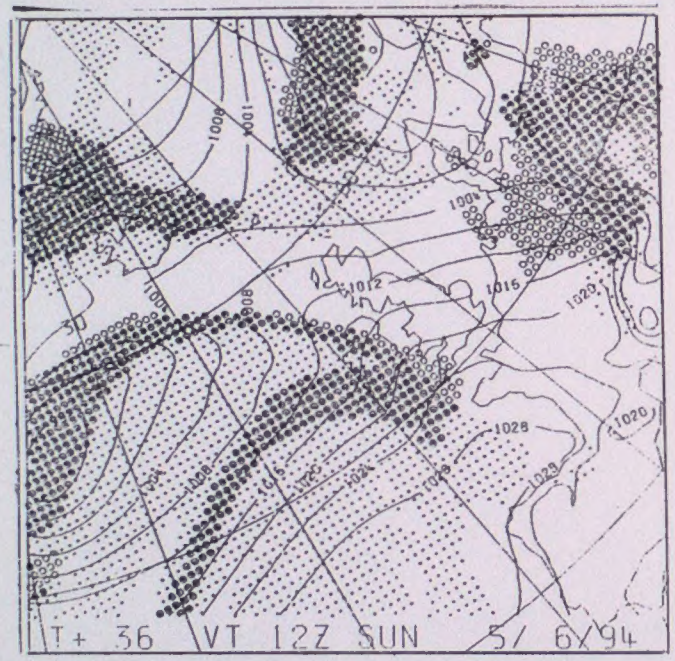
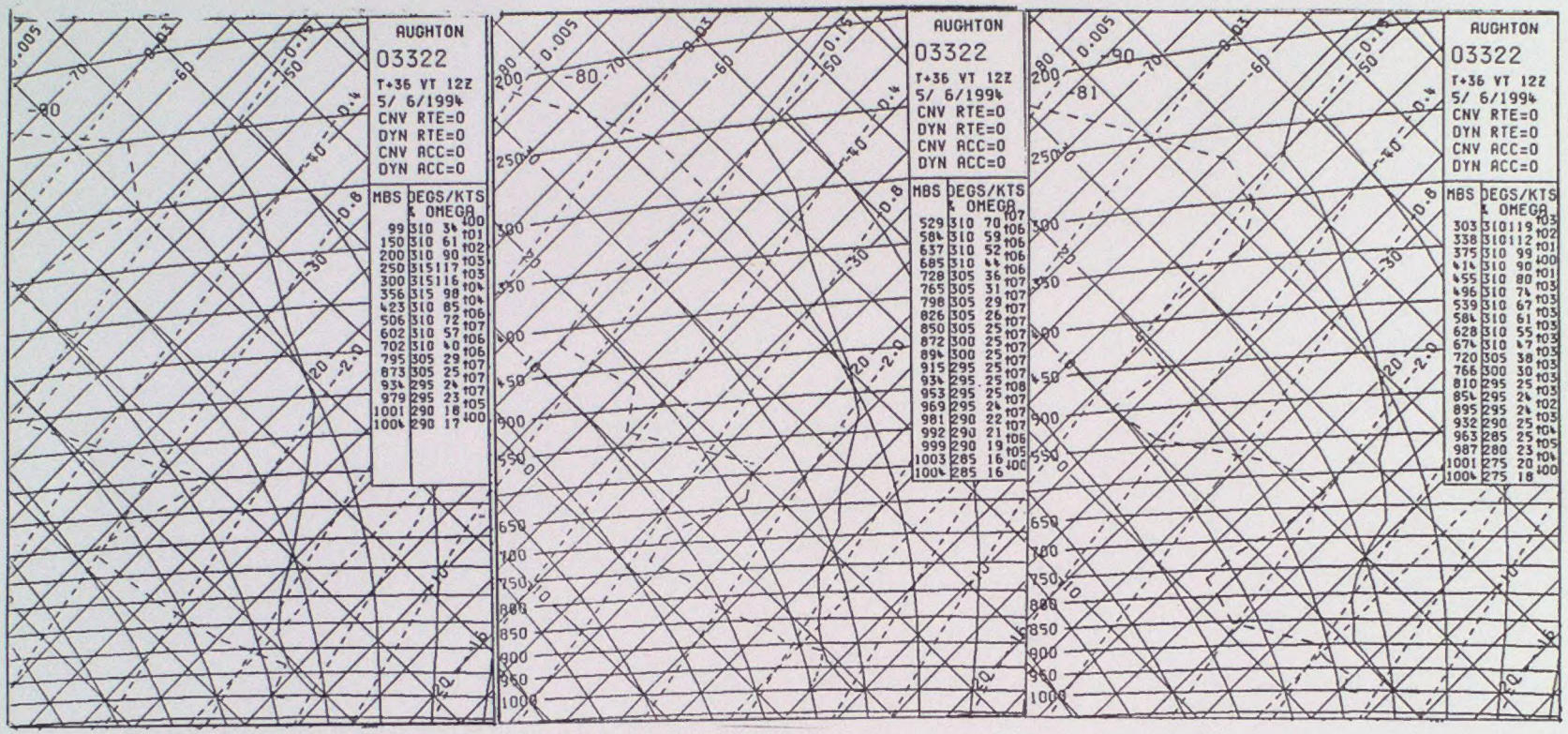


FIGURE 3.15

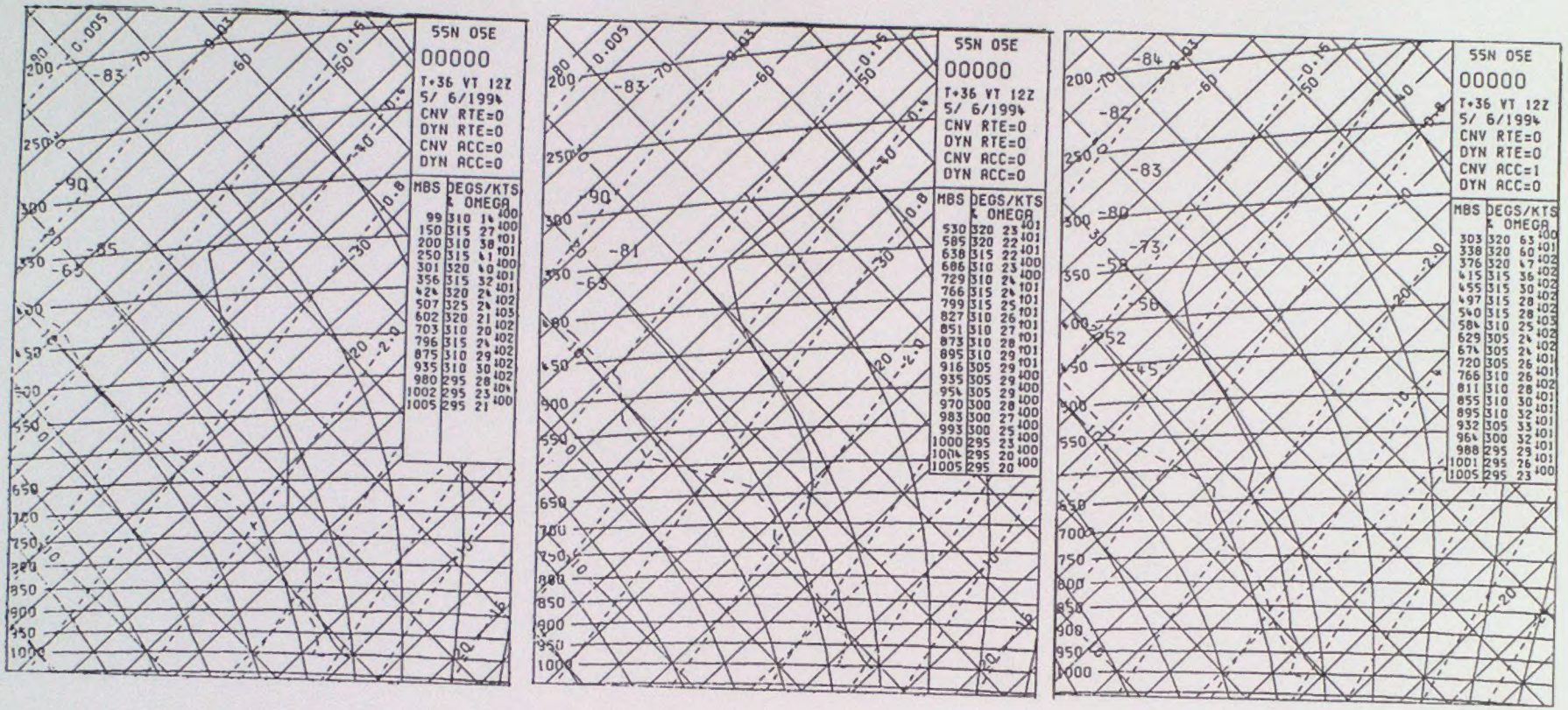
T+36 cloud forecast verifying
at 12z 05/06/94
o->4 octas medium cloud
.->4 octas low cloud
(a) operational (b) 31 levels (meslevs)
(c) 31 levels (eclevs)



a b c

FIGURE 3.16

Model forecast ascents
T+36 ascent for Aughton
VT 12z 05/06/94
(a) Operational
(b) Meslevs
(c) Eclevs



a b c

FIGURE 3.17

Model forecast ascents
T+36 ascent for 55N 05E
VT 12z 05/06/94
(a) Operational
(b) Meslevs
(c) Eclevs